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IN THE UNITED STATES DISTRICT COURT
FOR THE CENTRAL DISTRICT OF CALIFORNIA

STATE OF CALIFORNIA, on behalf of the CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL, Plaintiff, vs. UNITED STATES OF AMERICA, DEPARTMENT OF THE ARMY, and DOES 1 - 100, inclusive. Defendants.	No. CV 96-5205MRP(VAPx) No. CV 96-8867MRP(VAPx) (Consolidated)
CITY OF SAN BERNARDINO MUNICIPAL WATER DEPARTMENT, Plaintiff, vs. UNITED STATES OF AMERICA, DEPARTMENT OF THE ARMY, and DOES 1 - 100, inclusive. Defendants.	APPENDIX OF EXHIBITS IN SUPPORT OF UNITED STATES MOTION FOR SUMMARY JUDGMENT ON THE FIRST CAUSE OF ACTION AND PART OF THE THIRD CAUSE OF ACTION OF THE CITY'S COMPLAINT VOLUME 2 OF 6 Date: February 21, 2000 Time: 10:00 a.m. Room: Courtroom 12 Judge: Mariana R. Pfaelzer

APPENDIX OF EXHIBITS IN SUPPORT OF MOTION FOR SUMMARY JUDGMENT ON THE FIRST CAUSE OF ACTION AND PART OF THE THIRD CAUSE OF ACTION OF THE CITY'S COMPLAINT

Ex. 18 - August 19, 1982 Memo from Chet Anderson to SEB Staff, subj.: Info on Tank Coatings, Dep. Ex. 514

Ex. 19 - October 4, 1982 Memo from Chet Anderson to SEB Staff, subj.: Tank Coatings - Corrections to 8-19-82 Memo, Dep. Ex. 515

Ex. 20 - October 5, 1982 Memo from W. C. Gedney to C. E. Anderson, subj.: City of San Bernardino Tank Coating Problems, Dep. Ex. 516

Ex. 21 - October 18, 1982 Water Dept. Memo from Joseph F. Stejskal to Herbert B. Wessel, subj.: Paint Required for Sycamore #1 Steel Reservoir, Dep. Ex. 545

Ex. 22 - November 9, 1982 Water Dept. Memo from Joseph F. Stejskal to Herbert B. Wessel, Dep. Ex. 546

Ex. 23 - November 1982 Article by William B. Harper titled, "Inspecting, paining, and maintaining steel water tanks," Dep. Ex. 559

Ex. 24 - December 6, 1982 Water Dept. Memo from Joseph F. Stejskal to Herbert B. Wessel, subj.: Mountain Reservoir, Dep. Ex. 547

Ex. 25 - January 12, 1983 Memo from Joe Como to John M. Gaston, subj.: Coal Tar Interior Coatings in Potable Water Tanks

Ex. 26 - April 21, 1983 Memo from W. C. Gedney to C. E. Anderson, subj.: Tank Coating Problems - San Gabriel Valley Water Co., Dep. Ex. 520

Ex. 27 - May 16, 1983 Memo from K. W. Campbell to All Large Community Water Systems in Imperial, Riverside, and San Diego Counties, subj.: Tank Coatings, Dep. Ex. 705

Ex. 28 - May 19, 1983 Memo from Franklin T. Hamamura to All Large Community Water Systems, subj.: Coatings For Storage Reservoirs, Dep. Ex. 521

Ex. 29 - June 8, 1983 Dept. of Health Sanitation and Radiation Laboratory Results of Drinking Water Samples for Chemical Analysis from Mountain Tank, Dep. Ex. 519

Ex. 30 - June 30, 1983 City Classification of Pipe, Dep. Ex. 500

Ex. 31 - October 6, 1983 Field Form For Water Works Review, Joe Bocanegra and Larry Cox, Engineering Supervisor, persons contacted, Dep. Ex. 522

Ex. 32 - November 9, 1983 Interim Report on Warranty Inspections-Interior Coatings of Four Steel reservoirs by Harper & Associates Inspection Services, Dep. Ex. 590

Ex. 33 - Report by Joseph P. Como, P. E., CA Dept. of Health Services, titled, "California Survey of Solvents Leaching From Cold-Applied Coal Tar Paints Used As Internal Coatings In Potable Water Storage Tanks"

Ex. 34 - Job Description Chart, Lowe Dep. Ex. 579

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TCE/PCE Contaminated Water to East Twin Creek Flood Control Channel, Dep. Ex. 550, Doc. Prod. # CITY 01912

Ex. 52 - May 1984 Report titled, "Water Quality Problems Associated with Reservoir Coatings and Linings by R. Scott Yoo, William M. Ellgas, and Raymond Lee

Ex. 53 - December 30, 1985 Memo from Peter A. Rogers to All Large Public Water Systems, subj.: Tank Coatings, Dep. Ex. 528

Ex. 54 - August 14, 1986 Amended Permit by Peter A. Rogers, Dep. Ex. 710, Doc. Prod. # CITY 05-0214-05-0223

Ex. 55 - August 1986 Final Report titled, "Investigation of Sources of TCE and PCE Contamination in the Bunker Hill Ground Water Basin," submitted by URS Corp. to CA Regional Water Quality Control Board Santa Ana Region, Riverside, CA, Dep. Ex. 554, Doc. Prod. # CITY 00140-00265

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Ex. 56 - November 19, 1987, Draft Report by William B. Harper titled, "Coal Tar Enamel as a Water Tank Lining - - Past, Present and Future," Dep. Ex. 562

Ex. 57 - April 25-29, 1988 Public Water Supply Branch Annual Inspection Report , Dep. Ex. 501

Ex. 58 - April 1992 Report by Joseph F. Stejskal titled, "Municipal Wellhead Treatment - A Water Department's Perspective," Dep. Ex. 542

Ex. 59 - June 10, 1994 Soil Test Report by William B. Harper, Dep. Ex. 591, Doc. Prod. # CITY 12-1101-12-1109

Ex. 60 - February 25, 1999 Executed Declaration of Joseph F. Stejskal, Dep. Ex. 551

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Ex. 63 - Undated Map "City of San Bernardino Water Distribution System," Dep. Ex. 544 (Oversized)

Ex. 64 - September 30, 1977 Invoice for 1,000 Drums of TCE

Ex. 65 - September 16, 1977 Invoice for 30 gallons of Koppers 2000C Thinner

Ex. 66 - January 7, 1981 Construction Order to Recoat Mallory Reservoir

Ex. 67 - January 15, 1978 Koppers Protective Coatings Bituminous Coatings List, Doc. Prod. # CITY 10-0900

Ex. 68 - December 18, 1979 Work Order for Wiggins Hill Reservoir, Doc. Prod. # CITY 01-

Ex. 69 - February 19, 1982 Work Order for Mountain No. 3 Reservoir, Doc. Prod. # CITY 01-4052

Ex. 70 - Undated Engard Coatings Corp. Technical Data Sheet for Engard 800 Super Tank Coating, Doc. Prod. # CITY 10-1298-10-1303

Ex. 71 - July, 1953 Plans and Specifications No. 603, "For the Furnishing and Erection of a Welded Steel Water Storage Tank For The Del Rosa System," (Excerpts)

Ex. 72 - June, 1954 Plans and Specifications No. 616, "For the Furnishing and Erection of a Welded Steel Water Storage Tank For The Quail Canyon System," (Excerpts)

Ex. 73 - May, 1955 Plans and Specifications No. 625, "For the Furnishing and Erection of a Welded Steel Domestic Water Storage Reservoir For The Terrace System," (Excerpts)

Ex. 74 - Undated Plans and Specifications No. 636, "For the Furnishing and Erection of an Elevated Steel Water Storage Reservoir Which is Designated As Terrace Reservoir No. 3," (Excerpts)

Ex. 75 - March, 1957 Plans and Specifications No. 642, "For the Furnishing and Erection of a Welded Steel Water Storage Tank For the Del Rosa System and Designated as Del Rosa Reservoir No. 2," (Excerpts)

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Ex. 77 - January, 1959 Plans and Specifications No. 662, "For the Furnishing and Erection of a Welded Steel Domestic Water Storage Reservoir for the Sycamore System," (Excerpts)

Ex. 78 - January, 1959 Plans and Specifications No. 672, "For the Furnishing and Erection of a Welded Steel Domestic Water Storage Reservoir for the Terrace System," (Excerpts)

Ex. 79 - November, 1976 Specifications No. 857, "For the Interior Cleaning, Descaling, and Relining of the Del Rosa Number Two Steel Water Tank," (Excerpts)

Ex. 80 - October 14, 1982 Koppers Protective Coatings Technical Data Sheet for Bitumastic Super Tank Solution

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Ex. 84 - October 14, 1982 Koppers Principal Types of Protective Coatings - A Short Court in Practical Paint Technology to Assist Consulting and Maintenance Engineers

Ex. 85 - November 17, 1982 Dept. of Health Sanitation and Radiation Laboratory Results of Drinking Water Samples for Chemical Analysis of Mountain Tank

Ex. 86 - April 6, 1981 Letter from Jim Watson to Atchison, Topeka & Santa Fe Railroad, Ex. 567, Doc. Prod. # CITY 08-1442

Ex. 87 - July 18, 1984 Letter from Fred Ehemann to Joe Stejskal, subj.: TCE & PCE results, Dep. Ex. 569, Doc. Prod. # CITY 08-1422

Ex. 88 - July 26, 1984 Letter from Jim Watson to Tim Lassen, Dep. Ex. 570, Doc. Prod. # CITY 08-1418

Ex. 89 - September 13, 1993 Environmental Control Inspection Report, Dep. Ex. 572, Doc. Prod. # CITY 04E-2083-04E-2086

Ex. 90 - September 10, 1999 Declaration of Henry R. Stoner

Ex. 91 - June 1981 Twelve Chapter Water System Master Plan by Camp Dresser & McKee Inc. and Willdan & Associates

Ex. 92 - May 24, 1994 Uniform Hazardous Waste Manifest Form, Dep. Ex. 552, Doc. Prod. # CITY 06209

Ex. 93 - July 15, 1999 Plaintiff City of San Bernardino Municipal Water Department's Response to Defendant's Third Set of Requests For Admission

Ex. 94 - March 22, 1995 Muscoy Plume Operable Unit Record of Decision; Part I: Declaration, Part II: Decision Summary, Part III: Responsiveness Summary

Ex. 95 - July 11, 1952 black and white aerial photograph from U.S. Geologic Survey, EROS Data Center (excerpt) (EPA administrative record)

Ex. 96 - August 5, 1975 color infrared aerial photograph from U.S. Geologic Survey, EROS Data Center (excerpt) (EPA administrative record)

Ex. 97 - October 1980 black and white aerial photograph from U.S. Geologic Survey, EROS Data Center (excerpt) (EPA administrative record)

Ex. 98 - June 17, 1999 Deposition Transcript - Chester E. Anderson

Ex. 99 - June 18, 1999 Deposition Transcript - Chester E. Anderson

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Ex. 119 -	February 1995 Revised Report Of Waste Discharge, Cajon Sanitary Landfill, Dep. Ex. 742
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Ex. 125 -	June 1989 Final Report Solid Waste Assessment Test (SWAT) Cajon Sanitary Landfill
Ex. 126 -	January 1995 Sampling And Analysis Plan
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Ex. 128 -	June 24, 1991 California Water Quality Control Board Santa Ana Region Clean Up And Abatement Order 91-95, Dep. Ex. 763
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Ex. 130-	November 11, 1998 "Wells Cleanup Settlement Gets Approval, The Press-Enterprise, Riverside, California
Ex. 131-	Mid-Valley Sanitary Landfill Expansion-Final Environmental Impact Report-Vol. 1, excerpt 4.6-10
Ex. 132 -	October 15, 1997 Deposition transcript - Kevin P. Mayer Deposition
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Ex. 139 -	Feb. 16, 1982 letter from Richard H. Jones, All-J Enterprises to Mike Lowe
Ex. 140 -	Undated Engard Coatings Corp. Technical Data Sheet for Engard 820 Super T & O Coating

Exhibit 35

State of California

Memorandum

To : Cliff Bowen,
Frank Hamamura &
Bill Gedney

Date : April 25, 1984

Subject: Tank Coating Policy

From : Clarence Young
Sanitary Engineering Branch
Berkeley - (415)540-2173

As you know, we are assigned to review the policy on tank coatings (See Gaston's Memo of April 12, 1983). In addition, new policies are needed regarding tanks with old coatings that have not been checked out and regarding new coatings with or without EPA approval. Attached is a historical summary prepared by Endel. Please review his suggestions and submit to me by May 4 your thoughts on this matter. Because of AB 1803 and our reduced staff, what would you consider to be a minimal and reasonable surveillance program to be conducted by SEB? I understand that this matter will be discussed at Asilomar. Please call if you have any questions.

Att.
cc: Pete Rogers

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DEFENDANTS' EXHIBIT 526 FOR ID
BRYAN LUI, CSR NO. 11223
DATE: 6-3-99
WITNESS: GEDNEY

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Ex. 35, Page 301

State of California

Department of Health Services

Memorandum

To : Clarence L. Young

Date : April 2, 1984

Subject: Approval of Water Tank Coatings

From : Endel Sepp ES

Historical

On May 11, 1979, Office of Legal Services gave an opinion that we have no statutory authority or even responsibility to approve water tank coatings (or any proprietary pfoducts). Subsequently, requests for approval were referred to EPA's Additives Evaluation Branch.

On April 25, 1980, the SEB issued "Interim Operating Plan for Los Angeles County Water Utilities with Organic Solvent Contamination" which established "action levels" of 5 and 4 ppb for TCE and PCE, respectively, and required analyses for those.

In early 1982, in the San Bernardino District, taste and odors and high PCE and TCE levels were traced to Koppers Supertank coatings (cold applied coal tar). This type of coating had been approved by both EPA and AWWA but not by EBMUD. The contaminants remain in water for years after application. Anderson proposed a policy statement, and meetings were held with Koppers representative. Consequently, a policy statement was drafted, and on August 17, 1982 was sent to all large water systems. The statement ("Tank Coatings") urged special precautions with the use of coal tar coatings (AWWA No. 6), including notification of SEB, proper curing, and testing before putting tank into service. A questionnaire "Problems Attributed to Tank Coatings" was to be filled out and sent to Berkeley.

Results of the questionnaire were summarized by Joe Como, the expert: of the 45% systems responding, 75% used coal tar products and 40% of those used Koppers product. (January 12, 1983)

In addition, special sampling on coal tar coatings was done in several districts for volatile organics. This was also compiled by Como, as well as technical information on various coatings (October 26, 1982 and January 12, 1983). A data form on coal tar coatings was developed and sent to districts.

A start was also made on the development of a list of approved coatings, using data from EBMUD, New York State, and EPA. The EPA's Additives Evaluation Branch regularly sends out advisories, called DWAAN; in 1983 they compiled a computerized list of all "approved" water additives, including tank coatings. These lists are kept in Berkeley office. (However, being on those lists doesn't mean that they won't leach chemicals into the water).

On November 29, 1982, Anderson urged discretion, because Koppers may consider sueing.

Present Status of Activity

On April 12, 1983 John Gaston issued guidelines to the SEB districts on the approval of storage reservoirs following application of a coating, a "Plan of Action." This is still in use. It requires the utilities to notify our districts, sample water before putting tanks in service for volatile chemicals, and document pertinent facts. Action levels for various solvents are also included. The main concern is with PCE and TCE contamination. Intermittent use of waters which exceed "Action Levels"is provided for.

Meanwhile (1981-1983) all three suppliers of coal tar coatings had switched their solvents from TCE and PCE to the less toxic Xylene and Toluene.

On October 17, 1983, Karol Enferadi, the/new "expert", summarized the problems with approval, and recommended vigorous monitoring and surveillance as the only thing we can do. Water not meeting the action levels is either not delivered to consumers, or is blended to safe levels before use.

In March, 1984, a summary was made of all problems experienced by the districts with various coatings. Koppers Supertank was still the main culprit for PCE and TCE. Some other coatings also gave high readings for Xylol and other solvents, but only a few exceeded the action levels. This is shown in the Appendix.

Issues of Concern

(1) Old Tanks. Some tanks which have been coated 10-15 years ago are now showing high levels of PCE and TCE when analyzed. Solutions:

(a) Require all systems with old tanks to analyze for volatile organics. (This would cause a lot of indignation). Require those with high organic levels to replace coatings with ones not containing PCE and TCE.

(b) Sample systems with old tanks ourselves. This would require additional field time and large lab expense.

(c) Sample only those old tanks which have been coated with cold applied coal tar (Koppers, Tnemec, Engard). However, this data is not always available or known.

(d) Consider replacement of cold applied coal tar coatings with enamels (hot applied) or epoxies (less solvents), or with those not containing PCE or TCE.

(2) Approval of Tank Coatings. How should we do it?

(a) Use EPA advisory lists. However, these lists only indicate EPA's opinion, not approval. EPA does its evaluation by comparing the chemicals present in a coating with similar

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ones in a previously approved one (based on data supplied by FDA); it doesn't do any testing now. The tests which were done previously only measured the total weight of organics leached, not the concentration of individual chemicals. Therefore, using the EPA list gives no guarantee of safety (Koppers Supertank was approved). (The EPA cannot retract approval of a compound if it is later found to leach organics.)

(b) By means of surveillance and by requiring monitoring before tank is put in service. This is what is done now. Either the tank is taken out of service (requires recoating) or water is blended.

(c) By warning all systems not to use certain products. This would get us in trouble with lawsuits - restraint of trade.

(d) Apply for legislation authorizing an approval program, including testing of chemicals. This would probably cost a lot of money, require more personnel, and involve approval of other proprietary products also.

(e) Do as now, and wait for EPA testing program. There appears to be a long wait for this.

(3) <u>Revision of the April 1983 Guideline.</u>

ES:dg

Appendix

WATER TANK COATINGS USED*
March 1984

Koppers Bitumastic Super Tank Solution (coal tar)
Solvent: PCE, TCE
Has caused in numerous occations taste and odor problems; PCE & TCE levels high and persist for many years. Some PAH's also found. Better curing has not worked or improved the problem. Not recommended for water tank use.

Koppers Supertank Solution (New)
(Since 1983) Solvent: Xylene, Methyl Isobutyl Ketone (MIK)
No problems reported so far.

Kopper 70-B Coal Tar Enamel
Solvent: No PCE or TCE)
Has caused some taste and odor problems, but with additional curing time problem disappeared.

Tnemec 46-465 (coal tar enamel)
Solvent: TCA-(1,1,1 trichloroethane)
Has had high TCA levels in some instances, probably due to inadequate curing time given.

Tnemec 46-465 (New)
Solvent (since 1981): Xylene, Toluene
No reports of problems

Engard 800, 820 (coal tar based)
Solvent: Xylol, Toluene, MIK
No problems reported.

Engard 470 (Epoxy)
Solvent: MIK, MEK
No problems reported.

Engard 300
Solvent: Xylene
Some Xylene present due to no ventilation used, but no significant problem.

Tnemec Vinolyne (Copolymer)
Solvent: Xylene, MIK
Gives initially high organic levels, but these decline after flushing.

Tnemec 46-465/Koppers 70-B Combination
Solvent: Xylol
Xylene level reported high. In L.A. trihalomethane levels 11-88 µg/l. Otherwise no problems.

*The coatings which have been reviewed by SEB District personnel in 1982-1984.

Mobile 78 Series HiBuilt
Solvent:
No information on problems.

Karlee Co. Perma Bar Coal Tar Waterproofing
Solvent: Toluene, methylethyl Ketone
PCE & TCE < 1 ppb, but naphtalene 47 ppb.
No other data.

Sherwin Williams Hi Solids Catalyzed Epoxy
Solvent:
Supposed to be alright.

Glid Guard Coal Tar Epoxy
Solvent: Xylol
No problems reported.

Glid Guard Vinyl Copolymer
No information.

Amercoat 33 Vinyl Topcoat
Solvent: Mixed hydrocarbons, MIK, Methyl ethyl Ketone
No problems reported.

Texaco Rustproof Compound L
Solvent:
Has caused taste and odor problems. Not recommended for potable water use.

Wisconsin Plasite Phenolic Epoxy
Solvent:
Caused taste and odors at MWD. Not recommended for potable water use.

Carboline 191 Tank Lining System
Solvent:
No adverse effects noted.

Dupont Vinyl and Glue
Solvent: PCE in glue
No great problem.

Vinyl Coatings (General)
Solvents: Xylene, toluene, ethyl benzene, styrene

Exhibit 36

State of California

Department of Health Services

Memorandum

To : Clarence Young
Sanitary Engineering Branch
Berkeley

Date : May 4, 1984

Subject: Tank Coating Policy

From : W. C. Gedney *W C Gedney*
Sanitary Engineering Branch
San Bernardino

As requested, I have reviewed the questions raised by Endel Sepp in his memorandum to you dated April 2, 1984 regarding approval of domestic water tank coatings. I have the following comments:

A. Under (1) Old Tanks (a) and (c) - Despite potential resistance to an SEB tank sampling program, it is important to note that at some point in the near future we will have an MCL for PCE and TCE. A systematic sampling program conducted over a reasonable period of time would be preferable to a "crash" program which could follow the establishment of the MCL's for PCE/TCE. This program could initially target those tanks known (or suspected) to have been coated with cold applied materials using AWWA Inside Paint System No. 6.

B. Under (2) Approval of Tank Coatings (b) and (c)-We have been fairly specific in the past in advising purveyors about the potential dangers of using those tank coating products which contain TCE/PCE. We have not said that they cannot use any specific brand name product per se, rather in any case the tank will need to meet the Action levels for PCE, PCE, TCA, etc. In addition, Koppers has come out with a new coating material which does not contain TCE/PCE. One recent problem we have run up against is that several purveyors have not been informing us when they recoat one of their tanks. An update to the August 17, 1982 notice would serve to remind them of the need to do this.

C. Under (3) April 1983 Guideline Revision - How many districts have sent out letters reminding their large water systems of the need to inform SEB prior to recoating a tank? Some kind of follow-up notice to all large water system purveyors reminding them of the problems encountered with tank coatings and of the above stated requirement is needed and should be done out of Sacramento. Included in this, there should be a modified tank coating data sheet to be completed by the purveyor for each system tank. These forms would then be returned to the respective SEB districts.

Regarding the "Plan of Action" proposed in Gaston's April 12, 1983 memo, we need to do the following:

1. Notify all large water systems in accordance with the plan.

2. Formulate and follow a uniform sampling program to sample all of the domestic water reservoirs currently in service. Since we still do not have an MCL for PCE/PCE this program could be done in conjunction with our routine annual survey's of each system.

In light of the fact that several water purveyors in the San Bernardino District have had to remove recently applied coatings specifically because of TCE/PCE problems, SEB should extend the tank coating policy to cover all domestic water reservoirs regardless of when the coating was applied. It would be best to determine what the extent of the problem is in these reservoirs on a systematic basis rather than waiting for an MCL from USEPA.

WCG:mo

cc: SEB-Sacto
SEB-San Diego
District

Exhibit 37

State of California — Department of Health Services

Except Form M 5-10-84 — Coating

Memorandum

To : Clarence Young

Date : May 4, 1984

Subject: Tank Coating Policy

From : F. T. Hamamura FTH

SUMMARY

The comments and recommendations presented are based on the extensive experience gained by the staff of the Santa Ana District during the past year.

RECOMMENDATION

I recommend that you consolidate the comments of our committee and present a draft of our "Tank Coating Policy" at our Asilomar meeting for discussion.

COMMENTS

I suggest that we develop a statewide schedule to sample all the old tanks ourselves. This schedule should be based on data received from our 1982 survey with higher priority given to old tanks which have been coated with cold applied coal tar.

We should continue with our current procedures regarding new tank coatings by means of surveillance and by requiring monitoring before the tank is "approved" to be put in service. I suggest that we issue a uniform procedure for all districts to implement. Attached is the written procedures used in the Santa Ana District.

Attachment

FTH:jc

cc: Peter A. Rogers
Clifford L. Bowen
William C. Gedney

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MAY 7 1984
Dept. of Health Services
San Bernardino

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Procedures For Storage Reservoirs Coatings

Procedures for approving the use of storage reservoirs after application of protective coatings are as follows:

1. Contact the Large Community Water Systems and inform them of our concerns (See attached sample letter dated May 19, 1983).

2. At the time that the water purveyor contacts you, fill out the (Sample attached) "Tank Coating Data Sheet." Note that most of the data sheet must be completed at a later date with a copy sent to our Berkeley technical staff.

   Request the purveyor to send us a copy of the technical data sheet on the coating(s) to be used and a Material Safety Data Sheet (MSDS) on the product. By regulation of Cal/OSHA the coating applicator should have received an MSDS from the manufacturer or supplier of the coating. The MSDS is required to inform workers of the hazardous chemicals they are using. It provides pertinent information and a profile of a particular hazardous substance or mixture. This, along with any technical data brochures, should tell us which volatile chemicals must be analyzed for in the water supply.

   You should also remind them to (1) follow the manufacturer's directions closely or require the contractor to follow them closely, (2) use Force Air Ventilation for proper curing, (3) wash and disinfect before filling, (4) provide a seven day soaking period following initial filling, (5) sample the water in the reservoir and have it analyzed by an approved laboratory for volatile organics, (6) provide our office with the results of these tests, and (7) get approval from our office to put the reservoir in service.

3. The following are some of the volatile organics commonly found in the cold applied coal tar coatings and may also be present in other coating systems:

Constituent	Recommended Action Level
Trichloroethylene (TCE)	5 ppb
Tetrachloroethylene (PCE)	4 ppb
Trichloroethane (TCA)	300 ppb
Xylene (Xylol)	620 ppb
Toluene (Toluol)	100 ppb
Methyl ethyl ketone (MEK)	appropriate level under review
Methyl isobutyl ketone (MIK)	appropriate level under review

   If the coating system is something other than a cold applied coal tar and if the volatiles to be sampled for are questionable, please consult with Karol Enferadi of the Berkeley technical staff. There is insufficient data to establish a chronic exposure level for MEK. EPA has established a 10 day exposure level of 750 ppb. MEK or MIK is a common ingredient in many formuations. If MEK or MIK does show up, consult with the Berkeley technical staff.

4. Based on all this information, you must establish the minimum volatile organic constituents for which test results must be obtained. Review the test results and determine acceptability of putting the reservoir in service.

5. The contamination of concern is at the nearest consumer's tap. The nearest consumer's tap is defined as the point after the reservoir in the distribution system closest to the nearest affected consumer. The sampling results you first receive from the water system will be at the reservoir only (after a seven day soaking period). If the reservoir has been properly disinfected and if the levels of contaminants are below the action levels, you may give oral approval to put the reservoir in service, followed with written conformation.

6. If the levels of contaminants are not below the action levels, you will have to make an engineering judgement on whether or not blending or other treatment can be accomplished to lower the levels below the action levels at the nearest consumer's tap. If you decide that blending or treatment may work, then the reservoir may be allowed to go on line. Samples should be taken after the reservoir goes on line for conformation of your judgement.

7. On an intermittent basis water exceeding the action levels at the nearest consumer's tap may be delivered to the consumers based upon the following schedule (water with more than one contaminant should use the most restrictive schedule):

	Concentration At The Nearest Consumer's Tap	Use Period/Year
a.	>1X to 2X ACTION LEVEL	No more than 6 mos/year
b.	>2X to 4X ACTION LEVEL	No more than 3 mos/year
c.	>4X to 8X ACTION LEVEL	No more than 1½ mos/year
d.	>8X to 10X ACTION LEVEL	No more than 30 days/year

The nearest consumer's tap should be sampled a minimum of monthly until two consecutive monthly samples are below the action level. Sampling should be done at a time when flow from the reservoir into the transmission lines is at the consumer's tap. If two consecutive monthly samples are below the action level, then sampling and restrictions may cease.

Utilities that anticipate serving water to consumers above the action levels must provide notice to their consumers. We will assist them in developing the notices.

8. Water containing greater than 10 times the action level shall not be delivered to the consumers. Instruct the purveyor to drain the reservoir following approved disposal discharge requirements and repeat the process until test results are acceptable.

Attachments
5/19/83
FTH:jac

DEPARTMENT OF HEALTH SERVICES
SANITARY ENGINEERING BRANCH
Santa Ana District
28 Civic Center Plaza, Room 325
Santa Ana, CA 92701
Phone: (714) 558-4410

May 19, 1983

TO: All Large Community Water Systems

SUBJECT: COATINGS FOR STORAGE RESERVOIRS

Our investigation of taste and odor complaints from tank coatings so far have only implicated the coal tar coatings. High concentrations of some volatile chemicals have been found in water that has been in contact with these coatings. A memo dated August 17, 1982, was sent to you to this effect (Attachment 1). There may be volatile fractions from the myriad of other coating systems that present an equally potential health hazard. For this reason, you are directed to implement the following procedures for all interior storage reservoir paints or other protective coatings:

1. Before coating any new or existing water reservoir, you will contact our office.

2. The manufacturer's recommendations on application must be closely followed. This includes effects of temperature and humidity on the application and curing.

3. Proper curing time must be provided, as recommended. Additional curing time before the tank is filled should be provided if possible. Forced air ventilation must be used for proper curing. Air should be drawn from the lowest part of the reservoir since volatile vapors are heavier than air. In some cases it may be necessary to extend cure time beyond the manufacturer's recommendations.

4. Following the curing period the reservoir must be washed and disinfected before filling. A seven day soaking period shall follow initial filling to determine the presence of any leached organics.

5. After a seven day soaking period, samples of the water in the reservoir must be taken and analyzed by an approved laboratory (Attachment 2) for volatile organics constituents.

6. The results of these tests shall be submitted to this office for review. If the test results are high, draining the initial water from the reservoir, flushing, refilling, and retesting will be required. If the test results are acceptable, we will then consent to putting the reservoir in service.

If you have any questions or comments, please feel free to contact our office.

Sincerely,

Franklin T. Hamamura

Franklin T. Hamamura
District Sanitary Engineer

cc: Engineering Consultants
Attachments
FTH:jc

TANK COATING DATA SHEET

NAME OF UTILITY: SEB# ☐☐-☐☐☐

NAME AND LOCATION OF TANK:

AMOUNT OF STORAGE:

DIMENSIONS OF TANK (ie-height, width, diameter):

WAS THIS A NEW OR RECOATED TANK? NEW ☐ RECOATED ☐

OUTLINE THE SANDBLASING PROCEDURE:

WAS COATING DONE BY THE UTILITY OR A CONTRACTOR? IF CONTRACTOR, GIVE NAME, ADDRESS, AND TELEPHONE NUMBER:

PLEASE FILL IN THE FOLLOWING TABLE:

COATINGS (in the order that they were applied)	ONE	TWO	THREE
MANUFACTURER AND NAME OF COATING			
DATE APPLICATION STARTED			
DATE APPLICATION COMPLETED			
WAS COATING CUT WITH THINNER?			
TIME CURED BEFORE THE NEXT COAT WAS APPLIED (except final coat)			
DRY THICKNESS OF COAT			
TEMPERATURE AND RELATIVE HUMIDITY AT TIME OF COATING AND DURING THE CURING TIME			
CURING TIME OF FINAL COAT			
WAS CONTINUOUS FORCED AIR VENTILATION USED AFTER FINAL COAT IN ACCORDANCE WITH AWWA D102-78 OR MANUFACTURERS SPECIFICATIONS?			

DRAW A CROSS-SECTIONAL DIAGRAM OF THE TANK SHOWING THE APPROXIMATE LOCATION OF ACCESS PORTS WHERE VENTILATION OCCURRED:

WAS SAMPLING DONE OF THE TANK WATER AFTER FILLING? YES ☐ NO ☐
IF YES, INDICATE HOW LONG THE WATER WAS IN THE TANK BEFORE SAMPLING AND WHAT ANALYSIS WAS PERFORMED AND THE RESULTS:

WHAT IS THE APPROXIMATE RETENTION TIME IN THE TANK?

Exhibit 38

State of California

F. [illegible] Coating

S. BERNARDIN

Department of Health Services

Memorandum

To : Cliff Bowen, Bill Gedney
& Frank Hamamura

Date : June 4, 1984

Subject: Tank Coating Policy

From : Clarence Young

Enclosed is a draft of the Tank Coating Policy. Because of the general expression of support of the existing policy at Asilomar, there is little change. The primary difference of this draft is a more concise statement of the policies and implementation plans. I have purposely left out the details on how to handle the problem of an improperly cured tank because of the great number of possibilities depending on the situation. Also, Berkeley is available for consultation.

Also, enclosed are several samples of coating report forms and notification letters. Please send me your comments by June 15.

Attachment

Bill

Re: 1st Page Implementation
CONTRADICTORY TO DISC. @ ASILOMAR
#1 – New updated Notice Sent Out NOW
CHAS

RECEIVED
1984
Health Services

United States Summary Judgment Motion,
Ex. 38, Page 315

DRAFT

TANK COATING POLICY

I Notification

Policy - The utility shall inform SEB whenever it plans to apply protective coating to a reservoir.

Implementation

a) The field engineer shall remind the utility of this policy during the annual inspection.

b) Future Annual Report shall include a reminder of this policy.

c) Future revisions of O & M or Waterworks Regulations shall include a statement of this policy.

II Coating Product Review

Policy - The utility shall submit information on proposed coating to SEB for review.

Implementation

a) The field engineer shall check with the district engineer or the Berkeley Technical Unit (Endel Sepp) regarding acceptability of coating. For new coatings when SEB has no experience, the field engineer shall obtain from the water utility detailed information on the coating and submit the information to Berkeley for review. Do not contact the coating manufacturer or dealer, but they may be referred to Berkeley by the water utility regarding information needed. In general, this should include the ingredients used in formulations of the coating, toxicological data, applications and curing requirements, copy of Material Safety Data Sheet and EPA letter of approval if approved. Berkeley shall review the information and advise on use of coating including sampling requirements and permissible levels of contaminants.

III Water Sampling

Policy - The water utility shall sample the water stored in the coated reservoir to determine absence of significant levels of contaminants and submit results to SEB for review and approval.

Implementation

a) The field engineer shall require the utility to carry out this policy.

b) If significant amounts of contaminants are found, the field engineer shall follow up on corrective measures to be taken by the utility and contact Berkeley for advice.

IV Application Report

Policy - The field engineers shall submit a report on each coating job to Berkeley.

Implementation

a) The report should be made on the attached form.

b) Berkeley shall review the reports and prepare an evaluation of the data annually.

V Existing Coated Tanks

Policy - The water utility shall be required to sample existing coated reservoirs to determine absence of coating contaminants.

Implementation

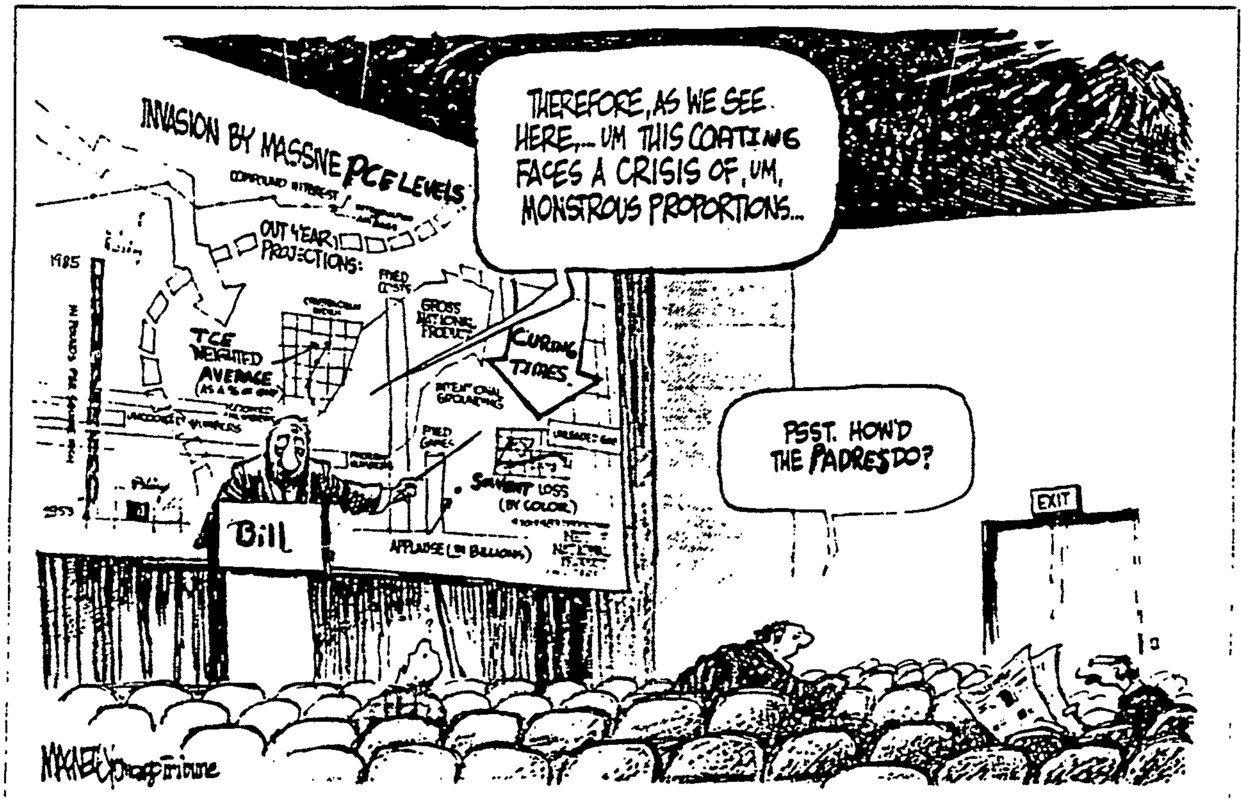
a) The Chief shall send a general letter to all utilities requesting sampling and report to SEB

b) The District Engineer shall follow up on the Chief's letter according to the following priorities.

1. System known to have used coal tar coating or taste & odor complaints.

2. System scheduled for annual inspection

GEDNEY'S PRESENTATION



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STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF HEALTH SERVICES
SANITARY ENGINEERING BRANCH
Santa Ana District
28 Civic Center Plaza, Room 325
Santa Ana, CA 92701

Phone: (714) 558-4410

May 19, 1983

TO: All Large Community Water Systems

SUBJECT: COATINGS FOR STORAGE RESERVOIRS

Our investigation of taste and odor complaints from tank coatings so far have only implicated the coal tar coatings. High concentrations of some volatile chemicals have been found in water that has been in contact with these coatings. A memo dated August 17, 1982, was sent to you to this effect (Attachment 1). There may be volatile fractions from the myriad of other coating systems that present an equally potential health hazard. For this reason, you are directed to implement the following procedures for all interior storage reservoir paints or other protective coatings:

1. Before coating any new or existing water reservoir, you will contact our office.

2. The manufacturer's recommendations on application must be closely followed. This includes effects of temperature and humidity on the application and curing.

3. Proper curing time must be provided, as recommended. Additional curing time before the tank is filled should be provided if possible. Forced air ventilation must be used for proper curing. Air should be drawn from the lowest part of the reservoir since volatile vapors are heavier than air. In some cases it may be necessary to extend cure time beyond the manufacturer's recommendations.

4. Following the curing period the reservoir must be washed and disinfected before filling. A seven day soaking period shall follow initial filling to determine the presence of any leached organics.

5. After a seven day soaking period, samples of the water in the reservoir must be taken and analyzed by an approved laboratory (Attachment 2) for volatile organics constituents.

6. The results of these tests shall be submitted to this office for review. If the test results are high, draining the initial water from the reservoir, flushing, refilling, and retesting will be required. If the test results are acceptable, we will then consent to putting the reservoir in service.

If you have any questions or comments, please feel free to contact our office.

Sincerely,

United States Summary Judgment Motion, Ex. 38, Page 319

Franklin T. Hamamura
Franklin T. Hamamura
District Sanitary Engineer

cc: Engineering Consultants
Attachments
FTH:jc

Kerr

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY George Deukmejian, Governor

DEPARTMENT OF HEALTH SERVICES
SANITARY ENGINEERING BRANCH
1350 Front Street, Room 2050
San Diego, California 92101
Telephone: (619) 237-7391

MAY 19 1983

May 16, 1983

TO: All Large Community Water Systems in Imperial, Riverside, and San Diego Counties

FROM: K. W. Campbell, District Engineer
Sanitary Engineering Branch

SUBJECT: Tank Coatings

The Sanitary Engineering Branch has adopted a statewide policy regarding the procedures to be followed when storage tanks are to be coated or recoated. This policy was developed after water contamination incidents occurred with coal tar enamel coatings and concern was developed over the potentially equal hazard to health presented by the residual volatile fractions left by the myriad of alternative tank coating systems.

We request each water utility to provide this office with the following information in writing prior to coating or recoating any domestic water storage tank:

1. Identification of tank(s) to be coated.
2. Brand and name of coating(s) to be applied.
3. Technical data sheets for the coating(s).
4. Material Safety Data Sheet for the coating(s).
5. Contractor's name (if applicable)
6. Approximate dates of coating work to be done.

We further request each utility to take the following steps to reduce the possibility of consumers receiving water with residuals exceeding Recommended Action Levels established for various organic materials:

1. Follow all recommendations set forth by the manufacturers for the coatings closely. This includes not only those recommendations for preparation of the surface and the thickness of the material applied but also those for controlling the effects caused by unfavorable temperature and humidity conditions on the application and curing. If weather conditions will different than recommended, the manufacturer should be contacted for specific instructions.

2. Forced Air Ventilation must be used for proper curing. Air should be drawn out from the lowest part of the tank since the volatile organic vapors are heavier than air. If there is any doubt about the adequacy of the curing conditions, additional curing time with continued forced air ventilation should be provided. Experience, though limited, has shown reduction of organics can be achieved in the amount of time suggested only if conditions are near ideal.

3. Following the curing period the tank must be washed and disinfected before filling. A seven day soaking period followed by determination of the presence of any leached organics must precede the placement of the tank in service. Samples of the water in the tank must be taken and analyzed by an approved laboratory for specified organic compounds. The tests to be run will be determined by this office after review of the information submitted prior to start of the work. Enclosed for your convenience is a copy of the latest list of laboratories approved for organics analysis.

4. A report of the above tests results must be sent to this office for evaluation. Approval must be received from this office before delivering water from the tank to consumers. The following table lists some of the volatile organics commonly found in cold applied coal tar coatings. Unrestricted use of the tank will be allowed if constituent concentrations are below the Recommended Action Level. The list below is not all inclusive and additional tests may be required.

Constituent	Recommended Action Level
Trichloroethylene (TCE)	5 ppb
Tetrachloroethylene (PCE)	4 ppb
Trichloroethane (TCA)	Appropriate level under review
Xylene (Xylol)	620 ppb
Toluene (Toluol)	100 ppb
Methylethyl Ketone (MEK)	750 ppb*

*This is a ten day exposure level.

5. Also enclosed is a tank coating data sheet. Please make copies and return a completed form to this office for each tank coated or recoated.

It should be noted that we are not approving or disapproving individual tank coating compounds, but are regulating the amount of organic constituents in water delivered to consumers.

☐☐ - ☐☐☐
Please Leave Blank

PROBLEMS ATTRIBUTED TO WATER TANK COATINGS

1. Name of Water System ______________________
2. Type of coating (name) ______________________
3. Date applied ______________________
4. Is coal tar lining used in distribution system? yes ☐ no ☐
5. If yes, in tanks? yes ☐ no ☐ In mains or transmission lines? yes ☐ no ☐
6. Problems experienced: Organics ☐ Taste & Odor ☐ Bacterial growth ☐ Other problems ☐ explain please.
7. Specific problems ______________________
8. Duration of problem ______________________
9. Corrective measures taken ______________________
10. Tank Details:
    a. Volume ______________________
    b. Depth ______________________
    c. Curing Time ______________________
    d. Other Tank Details ______________________

Please return to: Sanitary Engineering Branch
2151 Berkeley Way
Berkeley, CA 94704

COAL-TAR TANK COATING DATA SHEET

SEB# [ ][ ]-[ ][ ][ ]

NAME OF UTILITY:

NAME AND LOCATION OF TANK:

AMONT OF STORAGE:

DIMENSIONS OF TANK (ie-height, width, diameter):

WAS THIS A NEW OR RECOATED TANK? NEW [ ] RECOATED [ ]

OUTLINE THE SANDBLASTING PROCEDURE:

WAS COATING DONE BY THE UTILITY OR A CONTRACTOR? IF CONTRACTOR, GIVE NAME, ADDRESS, AND TELEPHONE NUMBER:

PLEASE FILL IN THE FOLLOWING TABLE:

COATINGS (in the order that they were applied)	ONE	TWO	THREE
MANUFACTURER AND NAME OF COATING			
DATE APPLICATION STARTED			
DATE APPLICATION COMPLETED			
WAS COATING CUT WITH THINNER?			
TIME CURED BEFORE THE NEXT COAT WAS APPLIED (except final coat)			
DRY THICKNESS OF COAT			
TEMPERATURE AND RELATIVE HUMIDITY AT TIME OF COATING AND DURING THE CURING TIME			
CURING TIME OF FINAL COAT			
WAS CONTINUOUS FORCED AIR VENTILATION USED AFTER FINAL COAT IN ACCORDANCE WITH AWWA D102-78 OR MANUFACTURERS SPECIFICATIONS?			

DRAW A CROSS-SECTIONAL DIAGRAM OF THE TANK SHOWING THE APPROXIMATE LOCATION OF ACCESS PORTS WHERE VENTILATION OCCURRED:

WAS SAMPLING DONE OF THE TANK WATER AFTER FILLING? YES NO

IF YES, INDICATE HOW LONG THE WATER WAS IN THE TANK BEFORE SAMPLING AND WHAT ANALYSIS WAS PERFORMED AND THE RESULTS:

WHAT IS THE APPROXIMATE RETENTION TIME IN THE TANK?

Capt Anderson
BV
JV
Tank Coatings

Clarence Young
SEB - Berkeley

June 1, 1984

Tank Coating
Experiences

Richard L. Haberman
SEB - Fresno

Listed below are the results of VOA samples taken from tanks treated with Koppers Super Tank Types II and III. You will note that the one tank treated with Type III has not been a problem. I contacted the one company who was responsible for coating all of the tank listed. They informed me that they do not intend to use any Type II material in the future and that they would sell it to their competitors if they had any.

Type II Tanks

City of Firebaugh
Tank No. 1

Sampling Point	Date Collected	VOA (ppb) TCE	VOA (ppb) PCE
Drain	11/14/83	2.5	17
Drain	11/14/83	1.6	11
Drain	12/1/83	.88	53
Tap	12/1/83	1.9	83 → what was done
Drain	12/30/83	Trace	1.0
Drain	2/2/84	--	6.6

Tank No. 2

Sampling Point	Date Collected	VOA (ppb) TCE	VOA (ppb) PCE
Drain	10/5/83	<0.5	<0.5
Tap	10/11/83	<0.5	<0.5
Drain	10/11/83	<0.5	<0.5
Drain	10/11/83	<0.5	<0.5 ← ? Analysis
Drain	11/14/83	.35	40
Drain	12/9/83	<0.5	9.88
Drain	12/30/83	<0.5	<0.5
Drain	2/2/84	--	1.7

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United States Summary
Judgment Motion,
Ex. 38, Page 327

Pinecrest Permittees Association
1. 98,000 Gallon Tank

Date Sampled	PCE (ppb)
9/3/82	11
9/28/84	12
3/28/84	15

for years

Type III Tank

East Sonora Water Company
1. Tank

Date Sampled	PCE (ppb)
2/1/84	N.D.
2/29/84	.51
2/29/84	N.D.
3/28/84	N.D.
3/28/84	N.D.

Only the chemicals detected are listed above. Cunnings and Cunnings, Inc. (phone 209-233-1761) at 472 South Teilman Avenue, Fresno, did all the tanks listed above.

RLH/jw

cc: SEB - San Bernardino, Chet Anderson
Sacramento
Fresno

United States Summary
Judgment Motion,
Ex. 38, Page 327

Exhibit 39

c✓

File Reservoir Coating

State of California

Department of Health Services

Memorandum

RECEIVED
JUN 14 1984

To : Clarence Young

Date : June 13, 1984

Subject : Tank Coating Policy

From : F. T. Hamamura FTH

After reviewing your draft of the Tank Coating Policy, I have the following comments:

1. Implementation plan for Part III, Water Sampling, should contain more details such as the details contained in my "Procedures For Storage Reservoirs Coatings." We need to specify the kind of analysis required, i.e. volatile organic analyses. We need to specify what is "significant amounts of contaminants."

2. I strongly recommend that Part V, Existing Coated Tanks, be changed to say:

   Policy - The Sanitary Engineering Branch will collect samples from existing coated reservoirs to determine the absence of coating contaminants.

   Implementation

   a) The field engineer shall sample the water stored in each coated reservoir in accordance to the following priorities.

      1. Consumer complaints of taste and odor that implicates coated reservoirs.

      2. During the annual inspection.

         (a) coal tar coatings
         (b) unknown coatings
         (c) other than coal tar

   b) The District Engineer shall direct the utility to take corrective measures if significant amounts of contaminants are found.

   c) The field engineer shall follow up on these corrective measures to be taken by the utility.

cc: Clifford L. Bowen
William C. Gedney
Sacramento
Reading File

jc

Exhibit 40

File Tank Coating

State of California

Department of Health Services

Memorandum

To : Clarence Young

Date : September 20, 1984

Subject: Tank Coating Policy

From : W. C. Gedney WCG

I have the following additional comments on the Tank Coating Policy:

1. I agree with Frank Hamamura that SEB should collect samples from existing tanks and conduct the necessary analyses.

2. Prior to implementation of the sampling program for existing tanks, each District should select two or three systems for a trial run. Each system selected should have a mix of different tank coatings (coal tar, enamel, vinyl, etc.) and generic products (Koppers, Tnemec, Engard). This would give us an idea of how entensive any problem might be and would allow us to gage the impact on Laboratory resources and capabilities. The trial run could be conducted by the end of this year.

WCG:mo

cc: Frank Hamamura
Clifford L. Bowen
SEB-Sacto
SEB-San Diego
District

United States Summary Judgment Motion, Ex. 40 Page 329

Exhibit 41

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY

GEORGE DEUKMEJIAN, Governor

CC: BERK-Young

DEPARTMENT OF HEALTH SERVICES
SANITARY ENGINEERING BRANCH
1350 Front St., Rm. 2050
San Diego, CA 92101
Telephone: (619) 237-7391

OCT 1 1984
Dept. of Health Services
San Bernardino

INFO Bill Gedney

October 9, 1984

Mr. Robert Friedgen
General Manager
Helix Water District
P.O. Box 518
La Mesa, California 92041

This will serve to confirm the items relative to water quality and tank coatings we discussed last week. The basic reference for our discussions was a letter dated May 16, 1983 sent from this office to all large community water systems. I brought out that another memorandum on tank coatings had been sent from our Berkeley headquarters on August 17, 1982 (copy enclosed).

The memos announced a state policy regarding procedures when storage tanks are to be coated or recoated. As the memos stated the Department declared the water distributed from the newly coated tanks must meet Recommended Action Levels given for various organic materials commonly found in tank coatings. Since Maximum Contamination Levels (MCL) have not been set for any of the materials no law is broken when the levels are higher than the Recommended Action Level. However, we firmly require the supplier to meet the recommend action level. And good waterworks practice will dictate like action whenever the contaminants are found in water distributed whatever their source.

The memos did not include existing tanks where no recoating was involved. It must be recognized, however, responsibile waterworks practice should include these tanks as the hazard is the same to the consumers served by the tanks. The Department is now studying the advisability to broadening the policy and have it include existing tanks. No time has been set as to when that action may take place.

Your cooperation and attention to this matter is a reflection of leadership in concern for the consumers we have often found in actions by the Helix Water District.

Kirkham W. Campbell

Kirkham W. Campbell
District Engineer

KWC:bjn
Enclosure

pc: San Diego County Dept. of Health Services
bpc: San Bernardino (Anderson)
Sacto (Rogers)

United States Summary Judgment Motion, Ex. 41, Page 330

Exhibit 42

State of California

Department of Health Services

Memorandum

To : Clarence Young

Date : November 7, 1984

Subject : Implementation of Tank Coating Policy

From : Bill Gedney Bill

I propose that SEB begin implementing the Tank Coating Policy by sending out from Headquarters an update to the August 7, 1982 memo to all large community water systems. This would include the following:

1. The requirement for advance notice to SEB before new or existing tanks are recoated.

2. An updated list of coating products that SEB has had experience with State-wide. This would summarize both good and bad experiences.

3. An attachment to the letter which outlines Recommended Procedures to be followed by purveyors before, during and after a tank is coated. These would include good coating specifications, competent inspections during the coating job and forced air ventilation.

4. Those new tanks coated with materials using IPS Nos. 1 or 6 will collect a sample and have it analyzed for VOA's by an approved lab.

5. Public notification will be required if systems serve water with organic chemical constituents greater than the respective Action Level.

6. SEB will be requiring additional testing of select tanks currently in service on a case by case basis following the annual review. If problems with existing tanks are found, additional corrective measures will need to be implemented (i.e. public notification, recoating, etc.). Also, each system will need to fill out new tank coating data sheet form for each tank.

Item No. 6 will be implemented for each system following the systems annual review in 1985. The criteria for selecting existing tanks to be sampled could be based on information gathered from the new data sheets in the following priority:

1. Known to have used Koppers Supertank solution.

DEFENDANTS' EXHIBIT 527 FOR ID
BRYAN LUI, CSR NO. 11223
DATE: 6-3-99
WITNESS: GEDNEY

United States Summary Judgment Motion, Ex. 42, Page 331

2. Known taste and odor problems

3. Used IPS No. 6 (cold applied coal tar enamel-any manufacturer)

4. Used epoxy coating system (IPS No. 1).

WCG:mo

cc: Frank Hamamura
Cliff Bowen

bcc: SEB-San Diego
SEB-Sacto
District

Exhibit 4 3

State of California

Memorandum

Department of Health Services

To : SEB District Engineers

Date : November 14, 1984

FILE Subject : Water Tank Coatings

From : E. Sepp
Sanitary Engineering Branch
Berkeley

This is a summary of data on water tank coatings which have been submitted to Berkeley by the Districts since the 1982 survey (see my memo of April 2, 1984). I want to point out that all needed information is not being reported. So, if you want to benefit by the data, you should tell us the type and brand of coating used.

Attachment

I.D. NO.	Name of System	Date Applied	Type of Coating*	Brand	Problem
	NORTHERN AREA				
03-016	Amador Co. CSA #2	1984	3	Epoxy	--
12-019	Hydesville CWD	1983	3	Tuemec Epoxy	--
31-004	Lincoln	1984	1,2	Koppers 70B, Engard 800	
43-004	Gilroy	1983	1	Koppers Supertank	PCE, T&O
43-001	Los Altos Suburban	1983	1,2	Engard	PCE
43-012	Santa Clara	1984	1,2	Koppers 70B,	--
43-019	San Jose - Alviso	1976		Tnemec 465	
43-			2		PCE, THM
43-	San Jose WC (CWSC)	1983	3		PCE
41-006	Bear Gulch (CWSC)	1983	1	Koppers Supertank	PCE
41-007	San Carlos (CWSC)	1983	3		--
49-020	Sonoma CWA-Cotati	1983	1,2	Koppers	--
	FRESNO REGION				
10-035	Del Rey CSD	1984	1	Koppers Supertank	--
10-005	Firebaugh	1983	1	Koppers Supertank II	PCE
			1	Koppers Supertank III	--
15-003	Bakersfield (CWSC)	1983	1		--
15-017	Indian Wells W.D.	1984	3		--
16-009	Kettleman City CSD	1984	1		PCE
20-005	Yosemite Springs Pk	1984	3		PCE
20-	Yosemite Lakes Pk	1982	1	Koppers Supertank	PCE
20-007	Hillview WC	1983	3		PCE
	Sequoiyah Natl. Pk	1983	1	Koppers Supertank	PCE
55-004	Pinecrest Permittees		3		PCE
55-014	Gibbs Ranch WC		1	Koppers Supertank	T&O

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I.D. NO.	Name of System	Date Applied	Type of Coating*	Brand	Problem
55-008	Lake Don Pedro CSD	1983	3		PCE, THM
55-010	Crystal Falls WC	1983	3		PCE
55-011	Cold Springs WC	1983	1	Koppers Supertank	--
55-015	Cedar Ridge WC		3		PCE
55-	Peaceful Pines		3		PCE
55-022	Tuolumne R.W.D.		3		PCE
	LA & ORANGE COUNTIES				
30-042	South Coast CWD	1983	3		--
30-073	Moulton-Niguel WD	1983	3		--
19-009	Valley CWD	1984	1	Engard 800	--
19-	Paradise Springs Pk	1983	1	Koppers Supertank	PCE
19-033	Dominquez WC-Torrance	1983	1,2	Koppers 70B, Tnemec 465	--
19-036	East Los Angeles (CWSC)	1983	1		--
19-040	El Sequndo	1983	1,2	Koppers Supertank	THM
19-043	Glendale	1984	3	Epoxy	--
19-044	Glendora	1983	1,2	Koppers 70B, Tnemec 465	--
19-134	Hermosa-Redoudo (CWCS)	1983	1		--
19-166	Valley WC	1983	3	Engard	THM
19-	Rural Homes MWC	1983	3		--
19-067	LA Water & Power, Mountaingate	1983	1,3	Tnemec	THM
19-	LA Water & Power, Sativa	1963	1,2	Koppers Supertank	T&O
19-225	Las Virgenes MWD	1984	1	Koppers Supertank III	--

I.D. NO.	Name of System	Date Applied	Type of Coating*	Brand	Problem
	DESERT REGION				
13-004	El Centro	1983	3	Tnemec	PCE, TCE
13-007	Heber PUD	1983	1,2	Koppers	--
30-095	Santiago CWD	1984	1	Koppers Supertank III	--
33-002	Beaumont-Cherry Valley	1984	3		--
37-010	Helix WD	1983	3	Tnemec	--
	March AFB	1983	1	Perma Bar	THM
36-004	West San Bernardino	1983	1	Tnemec 465	THM
36-010	Baldy Mesa CWD	1983	1		PCE,TCA
36-013	Loma Linda	1984	1		PCE
36-028	Marygold MWC	1984	1	Tnemec 465	--
36-021	Fallsvale SC	1984	1	Koppers	PCE
36-034	Ontario	1984	1	Tnemec 465	--
36-039	San Bernardino	1984	3		PCE, TCE
36-041	San Gabriel Valley WC	1983	1	Koppers Supertank	PCE
36-052	Victor Valley CWD	1983	1	Tnemec	PCE
36-055	Yucaipa Valley CWD	1983	3		T&O
36-057	Riverside Highland WC	1984	2	Koppers 70B	PCE
36-064	East Valley WD	1983	1,2	Koppers 70B, Tnemec 465	--

*1-Coal tar, cold applied; 2-hot applied coal tar; 3-other or unknown

United States Summary Judgment Motion, Ex. 43, Page 336

Exhibit 44

State of California

Department of Health Services

Memorandum

To : C. E. Anderson

Date : November 21, 1984

Subject : Riverside Highland Water Company - New Tank Coating

From : Jeff Stone

This memo will document the problems experienced with the internal coating of the Riverside Highland Water Company's new 2.0 MG welded steel storage tank and the costly, time consuming measures taken to finally correct them. Attached is a summary of the PCE data gathered during the course of this project and a tank coating data sheet for the "re-coat".

Despite several written and verbal warnings issued to the Company by SEB concerning problems experienced with coal tar coatings, the Company contracted with West Coast Industrial Coatings (a subsidiary of San Luis Tank) to "coat the tank" (no specifications) and opted not to provide an on-site inspector.

The tank walls and ceiling were coated with Koppers Supertank Solution and the floor was coated with Koppers hot-applied coal tar enamel. Although the contractor initially claimed he did not use any "old" Koppers coating material or solvent, it became evident that he most likely had. This was later vertified by the contractor's own admission. Following the curing and 7 day "soaking" period, water in the tank was found to contain 34 ppb of PCE. The Company was advised by letter dated April 23, 1984, that the tank was not to be placed into service until it could be demonstrated to the satisfaction of this department that PCE levels could be reliably maintained below the 4.0 ppb Action Level. Additionally, the Company was advised that recoating was most likely the only reasonable solution to resolving the problem.

During the ensuing four months the tank sat empty as questions concerning liability and responsibility were dealt with between the company, the contractor and Koppers Corp. Numerous samples of coating material and solvent (applied and unused) were collected by the contractor and SEB during this period. The results did not provide us with extremely meaningful (or at least understandable) information other than to verify that PCE was indeed present in measureable amounts in the material applied to the tank, present in the "old" Koppers coating material and solvent, and present in the "new" Koppers coating material and solvent (see attached data summary sheet). Koppers has contended that PCE is not in the formulation of their new "2000 " solvent and that they do not add PCE to their Type III coating material.

EXHIBIT 706 6-17-99 NF

United States Summary Judgment Motion, Ex. 44, Page 337

COAL-TAR TANK COATING DATA SHEET

NAME OF UTILITY: Riverside Highland Water Company

SEB# 3 6 - 0 5 7

NAME AND LOCATION OF TANK: Van Buren

AMONT OF STORAGE: 2.0 Mg.

DIMENSIONS OF TANK (ie-height, width, diameter):

WAS THIS A NEW OR RECOATED TANK? NEW [X] RECOATED [ ]

OUTLINE THE SANDBLASTING PROCEDURE:

JAS COATING DONE BY THE UTILITY OR A CONTRACTOR? IF CONTRACTOR, GIVE NAME, ADDRESS, AND TELEPHONE NUMBER: West Coast Industrial Coatings, Incorporated P.O. Box 245 Paso Robles, California 93447 (805) 238-0888

'LEASE FILL IN THE FOLLOWING TABLE:

OATINGS (in the order that they were applied)	ONE	TWO	THREE
ANUFACTURER AND NAME OF COATING oppers Company, Koppers Super Tank	Type 3		
APPLICATION STARTED	7-24-84	9-3-84	
APPLICATION COMPLETED	7-27-84	9-8-84	
S COATING CUT WITH THINNER? Yes	Koppers 2000	Koppers 2000	
ME CURED BEFORE THE NEXT COAT WAS APPLIED xcept final coat)	Approximately 4 weeks		
Y THICKNESS OF COAT	6 - 8 mils	10 mils	
PERATURE AND RELATIVE HUMIDITY AT TIME COATING AND DURING THE CURING TIME	85 degrees 45%	100 degrees 65%	
INC TIME OF FINAL COAT	This tank has been curing from 9-8-84 and will continue until 9-22-84		
CONTINUOUS FORCED AIR VENTILATION USED ER FINAL COAT IN ACCORDANCE WITH AWWA 2-78 OR MANUFACTURERS SPECIFICATIONS?	Yes	Yes	Yes

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Riverside Highland Water Company

Coal-Tar Coating Summary - 2.0 MG Res.

"PCE"

Date	Location	Lab	Results	Comments
4-16-84	2.0 MG Res	SDHS	34 ppb	Water sample following 7-day det. time
3-1-84	drum # 1	Smith Emery	80 ppm	
	drum # 2	"	80 ppm	
	New Container	"	1.0 ppm	
	Floor @ N. side	"	33.9 ppm	
	Floor @ center	"	74 ppm	
	Floor @ S. side	"	38 ppm	
3-1-84	Floor coupon	JMM	6.1 mg/Kg	
	Kopper Type III from drum	"	32 ug/Kg	
-9-84	Kopper Solvent 2000C	SDHS	N.D.	Headspace analysis by GC/MS - Not a reliable result
	Kopper Type III from drum	"	0.5 ug/Kg	"
	Type III/Solvent mix	"	Present	Not quantified
-27-84	Kopper 2000 Solvent	"	10 ug/ml	ppm
	Kopper Type III from drum	"	231 ug/kg	ppm
	Type III/Solvent Mix	"	273 ug/g	ppm
30-84	Kopper Type III	"	35 ug/g	ppm
	Hot-applied Coupon	"	22.9 ug/g	ppm
	Thermac coal tar/solvent	"	2.4 ug/g	Honeyhill reservoir
-1-84	H2O after 7-day d.t.	"	7.5 ug/L	Tank had 18" of water
9-84	H2O after 15-day d.t.	"	1.7 ug/L	" drained 18", dried, refilled
84	7-day d.t.	"	2.1 ug/l	Collected @ top
	"	"	2.9 ug/l	Collected @ bottom

United States Summary Judgment Motion, Ex. 44, Page 339

Exhibit 45

J. Bocanegra
P. Squires
F. Ehemann
L. Cox
1-7-85

JOHN CAROLLO ENGINEERS

PHOENIX, AZ • WALNUT CREEK, CA
FOUNTAIN VALLEY, CA • VISALIA, CA
TUCSON, AZ

DATE: December 31, 1984

City of San Bernardino Municipal Water Department
P. O. Box 710
San Bernardino, CA 92401

Attention: Joe Stejskal **SUBJECT:** Bulletin

Gentlemen:

The following items are: ☐ Requested
☒ Enclosed
☐ Sent separately via

No. of Copies	DESCRIPTION
1	Harper & Associates, Inc., Special Bulletin
	RE: Contamination of Potable Water from Volatile Organic
	Compounds Leached from Tank Coatings

The above are submitted:

☐ At your request ☐ For your action
☒ For your information and/or files ☐ For your review and/or approval

General Remarks:

Encls.(x)

DEFENDANTS' EXHIBIT 563 FOR ID
BRYAN LUI, CSR NO. 11223
DATE: 6-16-99
WITNESS: HARPER, V.I

Copies to:

Very truly yours,
JOHN CAROLLO ENGINEERS

By:
Gail P. Lynch

United States Summary Judgment Motion, Ex. 45, Page 340

CITY02108
563

HARPER AND ASSOCIATES, INCORPORATED

CORROSION ENGINEERING CONSULTANTS

P.O. BOX 7518 • RIVERSIDE • CALIF • 92513 • (714) 780-9055

JCE-FV		
No.		
✓	GPL	✓
✓	GWK	
✓	Criss	
	LIB	
	FILE	

SPECIAL BULLETIN

SUBJECT: Contamination of Potable Water From Volatile Organic Compounds Leached From Tank Coatings

REFERENCE: Department of Health Services (DOHS) Tank Coatings Memorandum of 8/17/82

FACTS:

Contamination has resulted due to VOC's leached from newly applied tank coating systems.

Three manufacturers furnish solvent cutback coal tar coatings for water tank interiors:

One manufacturer eliminated PCE from their formulation prior to issuance of the DOHS memorandum.

Second manufacturer eliminated PCE from their formulation in September 1982.

Final manufacturer elimated PCE from their formulation in September 1983.

All solvent cutback coatings shipped to water tank coating projects in California AFTER SEPTEMBER 1983 WERE GUARANTEED BY THE MANUFACTURERS TO CONTAIN NO PCE WITHIN THEIR PRODUCTS.

Tests did reveal minor traces on occasions in quantities far below the 4 PPB level specified by DOHS and EPA.

Where application has been monitored with full-time quality control inspection, no cases of contamination with PCE have been reported by reliable sources.

On unmonitored or peripherally monitored projects, the following, (among others) contained excessive levels of PCE during testing of the retained water:

RECEIVED
DEC 22 1984
JOHN CAROLLO ENGINEERS
FOUNTAIN VALLEY OFFICE

CITY02109

United States Summary Judgment Motion, Ex. 45 Page 341

1. Tank Size: 2,000,000 Gallon
   Owner: Riverside Highlands Water Company
   Location: Grand Terrace, California
   Coating Contractor: West Coast Industrial Coatings, Division of San Luis Tank and Piping

   Coating Used: Koppers Bitumastic Super Tank Solution

2. Tank Size: 2,500,000 Gallon
   Owner: Victor Valley County Water District
   Location: Victorville, California
   Coating Contractor: Sparta Painting Company

   Coating Used: Tnemec 46-465 Hi-Build Coal Tar Coating

   A. After determination of excessive levels of PCE in retained water samples, tanks were additionally vented to allow sufficient curing and then filled and retested.

   B. As PCE levels were still excessive, Owners finally determined they could no longer tolerate loss of their tanks; they ordered tanks to be stripped or partially stripped of existing coating and recoated with non/PCE coating/ thinner.

   C. One of these tanks has passed VOC tests and is in service. The second tank has not yet been tested and returned to service.

   D. Materials were shipped to these projects AFTER SEPTEMBER 1983 -- CONTAINED NO PCE IN THE FORMULATION.

On the above noted coating projects, no ongoing inspection by the water utilities involved -- not known how PCE was introduced into the coatings.

REASONABLE ASSUMPTION:

PCE was introduced by the Contractor in thinner used to thin coating materials at jobsite.

UNFORTUNATELY:

No qualified coatings inspector was present to monitor this function, so no definite conclusions established.

HOWEVER:

Coating materials from the same batches furnished to these projects were utilized on other projects with no adverse effects.

FICTION:

Coating manufacturers were directly responsible for furnishing PCE laden coatings on noted projects.

Coating manufacturers have assumed liability for the PCE contamination on noted projects.

It is not necessary to maintain a qualified Quality Control Inspector on a coating project to insure the specified end result.

MORE FACTS:

The manufacturers of coating materials on the noted projects furnished products which complied with DOHS and EPA requirements.

Contractors apparently introduced PCE into the coatings through thinner containing PCE.

Projects were not monitored sufficiently to detect use of incorrect thinners or other specification violations.

PCE presence caused extended loss of storage tank service in excess of one year per project. Actual cost figures are not available, but it is obvious the affected utilities suffered considerable direct and indirect losses, plus inconvenience and embarrassment.

I trust this Bulletin will set the record straight on the noted projects and affix responsibility where it belongs. I welcome your questions, comments or suggestions, plus facts on similar projects.

William B. Harper

William B. Harper, P.E.
Registered Corrosion Engineer
Certificate No. CR 786

REGISTERED PROFESSIONAL ENGINEER WILLIAM B. HARPER CR 786 CORROSION STATE OF CALIFORNIA

pce-a

HARPER AND ASSOCIATES, INCORPORATED

CORROSION ENGINEERING CONSULTANTS

P.O. BOX 7518 • RIVERSIDE • CALIF • 92513 • (714) 780-9055

cc: P. Squires
J. Bocanegra
L. Cox
F. Ehemann
1-7-85

SPECIAL BULLETIN

SUBJECT: Contamination of Potable Water From Volatile Organic Compounds Leached From Tank Coatings

REFERENCE: Department of Health Services (DOHS) Tank Coatings Memorandum of 8/17/82

FACTS:

Contamination has resulted due to VOC's leached from newly applied tank coating systems.

Three manufacturers furnish solvent cutback coal tar coatings for water tank interiors:

One manufacturer eliminated PCE from their formulation prior to issuance of the DOHS memorandum.

Second manufacturer eliminated PCE from their formulation in September 1982.

Final manufacturer elimated PCE from their formulation in September 1983.

All solvent cutback coatings shipped to water tank coating projects in California AFTER SEPTEMBER 1983 WERE GUARANTEED BY THE MANUFACTURERS TO CONTAIN NO PCE WITHIN THEIR PRODUCTS.

Tests did reveal minor traces on occasions in quantities far below the 4 PPB level specified by DOHS and EPA.

Where application has been monitored with full-time quality control inspection, no cases of contamination with PCE have been reported by reliable sources.

On unmonitored or peripherally monitored projects, the following, (among others) contained excessive levels of PCE during testing of the retained water:

1. Tank Size: 2,000,000 Gallon
   Owner: Riverside Highlands Water Company
   Location: Grand Terrace, California
   Coating Contractor: West Coast Industrial Coatings, Division of San Luis Tank and Piping

   Coating Used: Koppers Bitumastic Super Tank Solution

2. Tank Size: 2,500,000 Gallon
   Owner: Victor Valley County Water District
   Location: Victorville, California
   Coating Contractor: Sparta Painting Company

   Coating Used: Tnemec 46-465 Hi-Build Coal Tar Coating

   A. After determination of excessive levels of PCE in retained water samples, tanks were additionally vented to allow sufficient curing and then filled and retested.

   B. As PCE levels were still excessive, Owners finally determined they could no longer tolerate loss of their tanks; they ordered tanks to be stripped or partially stripped of existing coating and recoated with non/PCE coating/thinner.

   C. One of these tanks has passed VOC tests and is in service. The second tank has not yet been tested and returned to service.

   D. Materials were shipped to these projects AFTER SEPTEMBER 1983 -- CONTAINED NO PCE IN THE FORMULATION.

On the above noted coating projects, no ongoing inspection by the water utilities involved -- not known how PCE was introduced into the coatings.

REASONABLE ASSUMPTION:

PCE was introduced by the Contractor in thinner used to thin coating materials at jobsite.

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UNFORTUNATELY:

No qualified coatings inspector was present to monitor this function; so no definite conclusions established.

HOWEVER:

Coating materials from the same batches furnished to these projects were utilized on other projects with no adverse effects.

FICTION:

Coating manufacturers were directly responsible for furnishing PCE laden coatings on noted projects.

Coating manufacturers have assumed liability for the PCE contamination on noted projects.

It is not necessary to maintain a qualified Quality Control Inspector on a coating project to insure the specified end result.

MORE FACTS:

The manufacturers of coating materials on the noted projects furnished products which complied with DOHS and EPA requirements.

Contractors apparently introduced PCE into the coatings through thinner containing PCE.

Projects were not monitored sufficiently to detect use of incorrect thinners or other specification violations.

PCE presence caused extended loss of storage tank service in excess of one year per project. Actual cost figures are not available, but it is obvious the affected utilities suffered considerable direct and indirect losses, plus inconvenience and embarrassment.

I trust this Bulletin will set the record straight on the noted projects and affix responsibility where it belongs. I welcome your questions, comments or suggestions, plus facts on similar projects.

William B. Harper

William B. Harper, P.E.
Registered Corrosion Engineer
Certificate No. CR 786

REGISTERED PROFESSIONAL ENGINEER
WILLIAM B. HARPER
CR 786
CORROSION
STATE OF CALIFORNIA

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Exhibit 46

HARPER AND ASSOCIATES, INCORPORATED

CORROSION ENGINEERING CONSULTANTS

P.O. BOX 7518 • RIVERSIDE • CALIF • 92513 • (714) 780-9055

SPECIAL BULLETIN

SUBJECT: Contamination of Potable Water From Volatile Organic Compounds Leached From Tank Coatings

REFERENCE: Department of Health Services (DOHS) Tank Coatings Memorandum of 8/17/82

FACTS:

Contamination has resulted due to VOC's leached from newly applied tank coating systems.

Three manufacturers furnish solvent cutback coal tar coatings for water tank interiors:

One manufacturer eliminated PCE from their formulation prior to issuance of the DOHS memorandum.

Second manufacturer eliminated PCE from their formulation in September 1982.

Final manufacturer elimated PCE from their formulation in September 1983.

All solvent cutback coatings shipped to water tank coating projects in California AFTER SEPTEMBER 1983 WERE GUARANTEED BY THE MANUFACTURERS TO CONTAIN NO PCE WITHIN THEIR PRODUCTS.

Tests did reveal minor traces on occasions in quantities far below the 4 PPB level specified by DOHS and EPA.

Where application has been monitored with full-time quality control inspection, no cases of contamination with PCE have been reported by reliable sources.

On unmonitored or peripherally monitored projects, the following, (among others) contained excessive levels of PCE during testing of the retained water:

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EXHIBIT 708 6/12/99 rjg

PENGAD-Bayonne N.J.

1. Tank Size: 2,000,000 Gallon
   Owner: Riverside Highlands Water Company
   Location: Grand Terrace, California
   Coating Contractor: West Coast Industrial Coatings, Division of San Luis Tank and Piping

   Coating Used: Koppers Bitumastic Super Tank Solution

The same contractor also coated a .35MG tank for the Crestline Village CWD - same lousy results!

2. Tank Size: 2,500,000 Gallon
   Owner: Victor Valley County Water District
   Location: Victorville, California
   Coating Contractor: Sparta Painting Company

   Coating Used: Tnemec 46-465 Hi-Build Coal Tar Coating

   A. After determination of excessive levels of PCE in retained water samples, tanks were additionally vented to allow sufficient curing and then filled and retested.

   B. As PCE levels were still excessive, Owners finally determined they could no longer tolerate loss of their tanks; they ordered tanks to be stripped or partially stripped of existing coating and recoated with non/PCE coating/ thinner.

   C. One of these tanks has passed VOC tests and is in service. The second tank has not yet been tested and returned to service.

   Was tested - Passed!

   D. Materials were shipped to these projects AFTER SEPTEMBER 1983 -- CONTAINED NO PCE IN THE FORMULATION.

On the above noted coating projects, no ongoing inspection by the water utilities involved -- not known how PCE was introduced into the coatings.

REASONABLE ASSUMPTION:

PCE was introduced by the Contractor in thinner used to thin coating materials at jobsite.

Both contractors actually admitted to the utilities that they had done this.

UNFORTUNATELY:

No qualified coatings inspector was present to monitor this function, so no definite conclusions established.

HOWEVER:

Coating materials from the same batches furnished to these projects were utilized on other projects with no adverse effects.

FICTION:

Coating manufacturers were directly responsible for furnishing PCE laden coatings on noted projects.

Coating manufacturers have assumed liability for the PCE contamination on noted projects.

It is not necessary to maintain a qualified Quality Control Inspector on a coating project to insure the specified end result.

MORE FACTS:

The manufacturers of coating materials on the noted projects furnished products which complied with DOHS and EPA requirements.

Now its A Fact →

Contractors apparently introduced PCE into the coatings through thinner containing PCE.

Projects were not monitored sufficiently to detect use of incorrect thinners or other specification violations.

PCE presence caused extended loss of storage tank service in excess of one year per project. Actual cost figures are not available, but it is obvious the affected utilities suffered considerable direct and indirect losses, plus inconvenience and embarrassment.

I trust this Bulletin will set the record straight on the noted projects and affix responsibility where it belongs. I welcome your questions, comments or suggestions, plus facts on similar projects.

William B. Harper

William B. Harper, P.E.
Registered Corrosion Engineer
Certificate No. CR 786

REGISTERED PROFESSIONAL ENGINEER
WILLIAM B. HARPER
CR 786
CORROSION
STATE OF CALIFORNIA

pce-a

Exhibit 47

DEFENDANTS' EXHIBIT 549 FOR
BRYAN LUI, CSR NO. 11223
DATE: 6-10-99
WITNESS: STEJSKAL, VII

TCE/PCE

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY

GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF HEALTH SERVICES
714/744 P STREET
SACRAMENTO, CA 95814

January 4, 1985

To: All Large Public Water Systems

TANK COATINGS

In 1982, we alerted you of our concerns regarding possible organic chemical contamination resulting from improper selection, application, and use of coatings for water storage facilities. At that time we suggested special precautions to be taken to minimize the hazards of this problem. Our experience has revealed that in many cases, organic chemical contaminants (i.e., TCE, PCE) leached from the coating material, exceed State action levels. When this occurs, we will not allow the storage facility to be placed into service until the contaminated levels are reduced to below the action level.

To verify the concentration of any organic chemical contaminant, the following actions shall be required whenever a storage facility is coated:

1. Following a seven day soaking period, the water in the tank shall be sampled to determine the presence of any leached organic chemicals. Samples of the water shall be analyzed by a laboratory certified by the State Department of Health Services for the presence of any volatile organics;

2. A report of the test results must be sent to our district office for evaluation and approval before delivering water from the tank to consumers.

Since it is difficult to correct coating problems after they are discovered, considerable care should be exercised in the selection and application of coating materials. Some of the important precautions to be considered are indicated below for your guidance:

1. Whenever a tank is proposed to be coated, you should contact our district office regarding the proposal. Although we have no authority to approve proprietary products, we may be able to advise you of additional precautions to be taken for certain coatings. This could help you avoid some problems later;

2. Only experienced and competent applicators should be employed to apply the coatings. The coating manufacturer's application recommendations must be closely followed, especially the curing ventilation and curing time. Whenever forced air ventilation is recommended, it should be used for proper curing. Air should be drawnout from the lowest part of the tank since the volatile organic vapors are heavier than air. If there is any

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549

doubt about the adequacy of the curing conditions, additional curing time with continued forced air ventilation should be provided. Experience has shown that the amount of curing time suggested by the manufacturer is adequate only if temperature and humidity conditions are near ideal. Following the curing period, the tank should be washed and disinfected before filling.

Since we began sampling of water for organic chemical contaminants, we have found several previously coated tanks to continue to leach significant amounts of solvent even several years after application of the coating. We, therefore, advise that you sample some of your previously coated tanks to determine whether a problem exists, especially if there have been taste and odor complaints. This coating problem may also affect coated pressure tanks although the problem may be minimal due to the large volume of water passing through the tank.

If this Branch can be of any assistance, please do not hesitate to contact one of our district offices.

Sincerely,

Peter A. Rogers, Chief
Sanitary Engineering Branch

Exhibit 48

Tank Coatings
Ad to Clarence Young

MONTE VISTA WATER DISTRICT

AT YOUR SERVICE

ROBERT W. THOMPSON
MANAGER-SECRETARY
TELEPHONE (714) 624-0035

April 12, 1985

San Bernardino County Health Department
606 East Mills St., Rm. 1011
San Bernardino, CA 92408
Attn: Chet Anderson

Subject: New 1.67 MG Steel Reservoir Tank Coating.

Dear Chet:

The District is in receipt of your memo requesting a more detailed explanation of the subject coating. Since your form makes it very difficult to clearly explain how we resolved the coating problem, accept this letter as a supplement to your form.

Following is a step by step explanation:

1. On October 8, 1984 sandblasting and coating of the tank was initiated. The procedure used was to sandblast an area in the morning and coat that area in the afternoon.

2. The top 12' was coated with Tnemec Super Tank and left to cure for two days. Then the bottom 12' was blasted and the Bitumastic Jet Set Primer applied in the same manner as the top 12'. The total time from start to finish was eight days.

3. On October 16, 1984 we discovered that the bottom coat of Bitumastic Jet Set Primer contained forms of PCE.

4. On October 17, 1984 the contractor proceeded to sandblast the bottom 12' to a "near white" finish, removing all traces of the Bitumastic Jet Set Primer.

5. On October 26, 1984 new batches of Bitumastic Jet Set Primer were delivered with confirmation from Koppers, the coating supplier, that no PCE contaminants existed in the product.

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6. On October 29, 1984 the recoating was completed using the new batch of Bitumastic Jet Set Primer.

7. On November 5, 1984 the contractor started applying the Koppers Coal Tar Enamel to the bottom 12' of the tank. This application took a total of five days.

8. A 12,000 CFM blower ran continuously 24 hours a day through all sandblasting and application of all coating material. The blower was positioned at the westerly top hatch noted as Hatch A on the attached drawing. The northerly top hatch noted as B on the attached drawing and the manhole located at the bottom of the tank on the northerly side remained opened at all times.

9. The tank was disinfected and filled on November 27, 1984. The disinfection procedures used were in accordance with Monte Vista Water District tank disinfection specifications 4.5.02 attached.

Hopefully the information contained herein will suffice with the attached information to answer all your questions. If you need any further information, please do not hesitate to contact the undersigned.

Sincerely,

Robert W. Thompson

Robert W. Thompson
Manager-Secretary
Monte Vista Water District

RWT:jrc

Enclosure

Klau
w/ request
for more
info!
3/7/85
C

COAL-TAR TANK COATING DATA SHEET

SEB# 3 6 - 0 2 9

NAME OF UTILITY: MONTE VISTA WATER DISTRICT

NAME AND LOCATION OF TANK: RESERVOIR #4

CAPACITY OF RESERVOIR: 1.67 MILLION GALLONS

DIMENSIONS OF TANK (ie-height, width, diameter):

WAS THIS A NEW OR RECOATED TANK? NEW [X] RECOATED [ ]

OUTLINE THE SANDBLASTING PROCEDURE:
INTERIOR SSPC - SP10 "NEAR WHITE"
EXTERIOR SSPC _ SP6 "COMMERCIAL BLAST"

WAS COATING DONE BY THE UTILITY OR A CONTRACTOR? IF CONTRACTOR, GIVE NAME, ADDRESS, AND TELEPHONE NUMBER: VALLEY SANDBLASTING (714) 657-6808
P.O. BOX 1403, HEMET, CA 92343

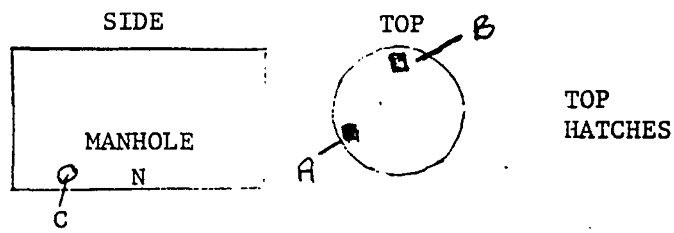
PLEASE FILL IN THE FOLLOWING TABLE:

COATINGS (in the order that they were applied)	TOP 12' ONE	BOTTOM 12' TWO	BOTTOM 12' THREE
MANUFACTURER AND NAME OF COATING	TNEMEC SUPER TANK COAT	BITUMASTIC JET SET PRIMER	KOPPER COAL TAR
DATE APPLICATION STARTED	OCT 8	OCT 26	NOV. 5
DATE APPLICATION COMPLETED	OCT 12	OCT 29	NOV. 9
WAS COATING CUT WITH THINNER? YES BRAND AND SPECIFICATION NUMBER:	MCKESSON CHEMICAL CO. X4LENE 4408177 JN1307		
TIME CURED BEFORE THE NEXT COAT WAS APPLIED (except final coat)	2 days	2 days	2 days
DRY THICKNESS OF COAT	1.5	1.5	3/32
TEMPERATURE AND RELATIVE HUMIDITY AT TIME OF COATING AND DURING THE CURING TIME	75°-80° DRY	75°-80° DRY	75°-80° DRY
CURING TIME OF FINAL COAT	AWWA SPEC.	AWWA SPEC.	AWWA SPEC. 23 days
WAS CONTINUOUS FORCED AIR VENTILATION USED AFTER FINAL COAT IN ACCORDANCE WITH AWWA D102-78 OR MANUFACTURERS SPECIFICATIONS? WHAT WAS CAPACITY OF BLOWER?	YES 12,000 CFM	YES 12,000 CFM	YES 12,000 CFM

HOW LONG WAS CONTINUOUS FORCED AIR VENTILATION PROVIDED? (TOTAL HOURS)

CONTINUOUS THROUGH ALL COATS.

DRAW A CROSS-SECTIONAL DIAGRAM OF THE TANK SHOWING THE APPROXIMATE LOCATION OF ACCESS PORTS WHERE VENTILATION OCCURRED:



"A" - Top hatch ~~of~~ blower Location
"B" - Open
"C" - Manhole open

WAS SAMPLING DONE OF THE TANK WATER AFTER FILLING? YES NO
IF YES, INDICATE HOW LONG THE WATER WAS IN THE TANK BEFORE SAMPLING AND WHAT ANALYSIS WAS PERFORMED AND THE RESULTS: 10 DAYS

SEE COPIES ATTACHED.

WHAT IS THE APPROXIMATE RETENTION TIME IN THE TANK?

44 HOURS

RESERVOIR No. 4

BROWN AND CALDWELL

ANALYTICAL LABORATORIES

LOG NO: P84-12-320

Received: 21 DEC 84
Reported: 09 JAN 85

JAN 10 1985

WESTERN ANALYTICAL LABS. INC.
13744 MONTE VISTA AVE.
CHINO, CA 91710

ATTN: JOE ZIMMER

PARTIAL REPORT OF ANALYTICAL RESULTS

OG NO	SAMPLE DESCRIPTION, AQUEOUS SAMPLES	DATE SAMPLED
2-320-6	4120946	

ARAMETER	12-320-6
rihalomethanes	
Date Extracted	01/02/85
Bromodichloromethane, ug/L	2
Bromoform, ug/L	2
Chloroform, ug/L	• 2
Dibromochloromethane, ug/L	2
Total Trihalomethanes, ug/L	8
PA Method 602	
Date Extracted	01/02/85
Ethylbenzene, ug/L	15
Toluene, ug/L	23
Other EPA Method 602, ug/L	<1

Edward Wilson, Laboratory Director

RECEIVED
JAN 1_ 1985
Monte Vista County Water District

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SECTION 4.5

of

DETAILED TECHNICAL SPECIFICATIONS

TESTING AND DISINFECTION

4.5.01 Testing

After tank erection is completed but before any surface preparation work commences, the tank shall be water tested. This shall be accomplished by filling the tank to the overflow limit with all valves closed but all piping open past the valves to permit the observation of any valve leakage. The water for any testing shall be furnished and paid for by the Contractor. For this purpose, the District will make available 1000 gallons per minute at the existing well site adjacent to the erection site. The water must stand with the inlet disconnected for 72 hours. No leakage will be permissible. The level gauge must prove to operate smoothly and accurately during filling and emptying. If any failure is observed, the cause is to be remedied and retested as above.

4.5.02 Disinfection

After all coating work is completed and accepted, the underside of the roof is to be washed with a high pressure hose stream with water containing 50 mg/L chlorine. Entry for this purpose shall be through a roof hatch. Hosing shall continue until at least 35,000 gallons has been used which would be an average depth of 6" in the tank. With all persons, materials and equipment removed from the tank, further filling to overflow with unchlorinated water will result in 1.0 mg/L chlorine. This is to stand at least 24 hours before useage. A continuous overflow of 200 gallons per minute for six hours will then skim off any floating material.

Exhibit 49

NORTH SAN BERNARDINO - MUSCOY SITE

HAZARD RANKING PACKAGE

STATE TOXICS BOND FUND LIST

PENGAD-Bayonne N J

EXHIBIT

709

6/18/99 rjp

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CITY01314

CALIFORNIA SITE EVALUATION

Facility name: North San Bernardino - Muscoy Area

Location: San Bernardino, San Bernardino County

EPA Region: Region IX

Person(s) in charge of the facility: No responsible party - an old, abandoned small-plane airport near wells is one suspect location as source of waste.

Name of Reviewer: C. E. Anderson, SEB, CDHS Date: April 20, 1985

General description of the facility:
(For example: landfill, surface impoundment, pile, container; types of hazardous substances; location of the facility; contamination route of major concern; types of information needed for rating; agency action, etc.)

Serious groundwater contamination including TCE, PCE and other volatile organics. Probable (most suspect) source of contamination for some of the wells is old airport. Other possible points of origin (less likely) are old military sites, softening plant, power plant, etc.

Scores: S_M = 42.24 (S_{gw} = 73.08 S_{sw} = NA S_a = NA)

S_{FE} = NA

S_{DC} = NA

FIGURE 1
PHI/HRS COVER SHEET

EVALUATION DATE: / /	EVALUATOR
April 22, 1985	C. E. Anderson & W.C. Gedney, DHS, SEB

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CITY01315

	S	S^2
Groundwater Route Score (S_{gw})	73.08	5340.7
Surface Water Route Score (S_{sw})	0	0
Air Route Score (S_a)	0	0
$S_{gw}^2 + S_{sw}^2 + S_a^2$		5340.7
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$		73.08
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2} / 1.73 = S_M =$		42.24

FIGURE 10
WORKSHEET FOR COMPUTING S_M

S_m		Cost Factor	Assigned Range	Cost Estimate, E_c
$S_{F\&E}$		1	$0 < E_c < 300,000$	
S_{oc}		2	$300,000 < E_c \leq 1,000,000$	
Total		3	$1,000,000 < E_c \leq 3,000,000$	
		4	$3,000,000 < E_c \leq 10,000,000$	
		5	$10,000,000 < E_c \leq 30,000,000$	
		6	$E_c > 30,000,000$	

$$S_m + S_{F\&E} + S_{oc} = \frac{\text{Total Benefits}}{\text{Cost Factor}} = \frac{TB}{CF} = I_{PR}$$

FIGURE 10A

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CITY01316

NORTH SAN BERNARDINO - MUSCOY AREA

Ground Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
Total Route Characteristics Score				15	
3 Containment	0 1 2 3	1		3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1		18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score			19	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3		9	
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1		40	
Total Targets Score			49	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			41895	57,330	
7 Divide line 6 by 57,330 and multiply by 100			S_{gw} = 73.08		

FIGURE 2
GROUND WATER ROUTE WORK SHEET

NORTH SAN BERNARDINO - MUSCOY SITE	s	s^2
Groundwater Route Score (S_{gw})	73.08	5340.7
Surface Water Route Score (S_{sw})	0	0
Air Route Score (S_a)	0	0
$S_{gw}^2 + S_{sw}^2 + S_a^2$		5340.7
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$		73.08
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2} / 1.73 = S_M =$		42.24

FIGURE 10
WORKSHEET FOR COMPUTING S_M

CALIFORNIA SUPERFUND

Hazard Ranking System Information Check List

SITE NAME: ______ DATE OF EVALUATION 4 / 22/ 85

EVALUATOR: C. E. Anderson & W. C. Gedney
SEB, DHS, San Berhardino

SECTION	INFORMATION OBTAINED	INFORMATION NEEDED
Groundwater		
Measured Level or Evidence of Release	X	
Depth to Lowest Point of Waste (In Groundwater)		X
Depth to Groundwater Aquifer	X	
Net Precipitation	X	
Permeability of Unsaturated Zone	X	
Containment (Assumed None)		X
Physical State of Waste (Assumed Liquid)		X
Persistence of Waste	X	
Waste Toxicity	X	
Infectiousness of Waste	NA	
Waste Quantity (Estimated)		X
Groundwater Use	X	
Groundwater Flow (Direction)	X	
Distance to Nearest Well Downgradient	X	
Population Served by Wells Within 3 Miles	X	
Surface Water NA		
Measured Level of Evidence of Release		
Site Slope, Terrain		
1-Year, 24-Hour Rainfall		
Distance to Surface Water		
Flood Potential		
Containment		
Surface Water Use		
Critical Habitats		
Population Served by Intakes Within 3 Miles		
Air NA		
Evidence of Release		
Volatility of Waste		
Reactivity of Waste		
Incompatibility of Waste		
Distance to Nearest Population		
Population Within One Mile		
Land Use		
Surface Area of Waste		
Prediction of Wells Affected by Groundwater Releases		
Prediction of Concentrations of Released Contaminants at Known Drinking Water Intake		
Concentrations in Waste [illegible]		

June 28, 1982

DOCUMENTATION RECORDS
FOR
HAZARD RANKING SYSTEM

INSTRUCTIONS: The purpose of these records is to provide a convenient way to prepare an auditable record of the data and documentation used to apply the Hazard Ranking System to a given facility. As briefly as possible summarize the information you used to assign the score for each factor (e.g., "Waste quantity = 4,230 drums plus 800 cubic yards of sludges"). The source of information should be provided for each entry and should be a bibliographic-type reference that will make the document used for a given data point easier to find. Include the location of the document and consider appending a copy of the relevant page(s) for ease in review.

FACILITY NAME: North San Bernardino - Muscoy

LOCATION: San Bernardino, San Bernardino County

NOTE: A list of references follows page 5 and all references are attached except Reference J which will be forwarded as soon as it is available.

GROUND WATER ROUTE

References
A,B,C,D

1 OBSERVED RELEASE

Contaminants detected (5 maximum):
1. Perchloroethylene
2. Trichloroethylene
3. Methylene chloride
4. 1,1,dichloroethane
5. cis 1,2 dichloroethylene

Rationale for attributing the contaminants to the facility:
Some wells are located directly downgradient and in very close proximity to an old municipal airport. Other wells are located downgradient from other potential sources of contamination (old army facility, softening industry, power plants, etc). Contaminants related to cleaning solvents likely used at some or all of source facilities.

* * *

2 ROUTE CHARACTERISTICS

Depth to Aquifer of Concern

Name/description of aquifers(s) of concern:
Bunker Hill Basin

F,G,H,I

Depth(s) from the ground surface to the highest seasonal level of the saturated zone [water table(s)] of the aquifer of concern:
140 feet

Depth from the ground surface to the lowest point of waste disposal/ storage:

Unknown - waste has reached GW table
(use 140')

CITY01321

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References **Net Precipitation**

Mean annual or seasonal precipitation (list months for seasonal):
Estimated 25 inches/yr. at Newmark location

Mean annual lake or seasonal evaporation (list months for seasonal):
Estimated 45 inches/yr.

Net precipitation (subtract the above figures):
Estimated - 20 inches/yr.

Permeability of Unsaturated Zone

,G,J **Soil type in unsaturated zone:**
Stratified gravel (coarse to fine) sand, clays

,G,J **Permeability associated with soil type:**
Highly permeable

Physical State

Physical state of substances at time of disposal (or at present time for generated gases):
Believed to be liquid (assumed)

* * *

CITY01322

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References 3 CONTAINMENT

Containment

Method(s) of waste or leachate containment evaluated:

None believed to be available
Disposal was most likely direct to natural ground surface or to pits

Method with highest score:

See above

4 WASTE CHARACTERISTICS

SAX Rating Toxicity and Persistence

Compound(s) evaluated:

Perchloroethylene
Trichloroethylene

Compound with highest score:

Perchloroethylene
Trichloroethylene

Hazardous Waste Quantity

Total quantity of hazardous substances at the facility, excluding those with a containment score of 0 (Give a reasonable estimate even if quantity is above maximum):

Est. 4½ tons is about twenty 55-gallon drums

Basis of estimating and/or computing waste quantity:

Rough mass balance on aquifer vs. concentrations found

* * *

References

K

K,L,M

5 TARGETS

Ground Water Use

Use(s) of aquifer(s) of concern within a 3-mile radius of the facility:

Domestic water; inadequate alternate sources of satisfactory quality (Domestic includes all municipal commercial, industrial and irrigation uses)

Distance to Nearest Well

Location of nearest well drawing from aquifer of concern or occupied building not served by a public water supply:

12 wells have shown actual contamination
11 have shown levels of at least one chemical above action level on at least one analysis.

Distance to above well or building:

Worst contaminated wells may be within several hundred feet of an old disposal area. (Newmark Wells)

Population Served by Ground Water Wells Within a 3-Mile Radius

Identified water-supply well(s) drawing from aquifer(s) of concern within a 3-mile radius and populations served by each:

39 wells. See reference M for listing.
NOTE: Only wells within 3 mile radius and located downgradient are included.

Computation of land area irrigated by supply well(s) drawing from aquifer(s) of concern within a 3-mile radius, and conversion to population (1.5 people per acre):

N/A

Total population served by ground water within a 3-mile radius:

The San Bernardino city wells could be used to serve any part of the City with a population of 140,000 persons. The Riverside wells would serve part of the City's 170,000 population.

LIST OF REFERENCES

A. Summary of Lab Results - Organics - San Bernardino City Wells

B. Summary of Lab Results - Organics - Southern California Water Company (SCWCo.) - Delman System Wells

C. Chronological Graphs of TCE/PCE Levels - San Bernardino City Wells

D. Chronological Graphs of TCE/PCE Levels - SCWCo. Wells

E. Map of Bunker Hill Groundwater Basin

F. Well Construction Data and Well Logs - San Bernardino City Wells

G. Well Construction Data and Well Logs - SCWCo. Wells

H. Water Level Hydrographs - San Bernardino City Wells

I. Water Level Hydrographs - SCWCo. Wells

J. Preliminary Engineering Geology Analysis of Groundwater Movement in the North San Bernardino Area - Gary S. Rasmussen & Associates, April, 1985

K. Map Showing Locations of San Bernardino City and SCWCo. Wells

L. Map Showing Direction of Groundwater Movement

M. List of Domestic Wells Within A Three Mile Radius Down Gradient of Known Groundwater Contamination Areas

SUMMARY
RESULTS OF TCE/PCE SAMPLES FROM THE CITY OF SAN BERNARDINO
ANALYZED BY THE DEPARTMENT OF HEALTH SERVICES SOUTHERN CALIFORNIA BRANCH LABORATORY SECTION
(EXCEPT WHERE NOTED [1, 2])
ALL VALUES ARE IN PARTS PER BILLION (ug/l)

	Newmark No. 1		Newmark No. 2		Newmark No. 3		Newmark No. 4		30th & Mt. View St.		31st & Mt. View St.		Leroy St.		Waterman	
ate ampled	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PC
/29 30/80	-	-	0.26	0.51	4.2	1 5	<.01	.03	4.7	5.3	6.9	8.2	4.6	6.6	1.0	1.4
/6/80	1.3	9.4	-	-	5.0	19	-	-	3.0	3.6	5.1	7.8	3.6	6.0	- -	-
/20/80	1.0	8.9	-	-	4.5	21	<.05	<.05	3.3	5.4	3.1	5.9	3.1	6.7	1.1	2.2
/27/80	1.0	9.0	-	-	3.8	20	-	-	3.5	4.8	4.2	7.5	3.8	8.2	-	-
/10/80	-	-	0.54	0.80	4.6	18	<.1	<.1	3.7	6.3	5.5	8.2	4.2	6.9	1.2	2.7
/26/80[1*]	-	-	-	-	3.9	18.8	<.25	<.25	-	-	-	-	2.9	5.2	-	-
/14 21/81	3.0	15	-	-	3.9	21	-	-	3.5	5.6	-	-	2.9	5.6	1.0	1.7
/18/81	2.1	16	-	-	4.3	21	-	-	-	-	-	-	-	-	-	-
1/24/81	-	-	0.60	1.7	5.3	29	-	-	-	-	3.0	5.3	-	-	-	-
/28/82	4.2	31	<.1	<.1	7.2	41	<.1	<.1	2.9	4.8	4.2	7.6	4.7	11.0[3]	2.4	4.4
/[illegible]3/83	2.7	13.7	<.2	1.1	10	51	0.88	5.1	4.5	6.4	3.8	6.4	3.8	7.8	1.3	.5
/[illegible] 3	5.7	42	0.29	2.4	12	73	<.1	<.1	3.0	5.9	2.5	4.3	0.7	2.6	-	-
1/7/83 *	3.3	22.4	<.2	< .2	-	-	< .2	< .2	1.1	2.1	2.6	4.0	1.6	5.4	-	-
1/13-18/84*	< .2	4.2	<.2	< .2	-	-	< .2	< .2	2.2	6.0	2.7	5.8	1.3	7.5	-	-
/14/84 *	2.0	18	-	-	13	72	< .2	< .2	-	-	-	-	-	-	-	-
/23/84 *	1.7	7.7	<1.0	<1.0	6.6	37	1.6	9.6	2.5	5.1	2.4	4.9	<1.0	4.8	<1.0	<1.0
0/8/84 *	3.9	24	1.1	7.4	14	68	4.9	28	2.1	3.7	2.9	3.2	1.5	6.5	-	-
/22/85 *	7.6	44	.5	2.0	16	84	10	52	2.6	4.4	3.4	3.7	2.5	11	-	-
/25/85	-	-	-	-	17	91[4]	-	-	-	-	-	-	-	-	-	-
/12/85	11	46[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
/28/85 [2]*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	2.9

1 Analyzed by the DOHS Sanitation and Radiation Lab in Berkeley
2 Analyzed by California Water Lab
3 Sampled on 10-14-82
4 These values represent the maximum level of TCE/PCE detected during a packed tower aeration treatment pilot test program.
* Analyses for purgeable halocarbons and aromatics conducted. Results summarized on attachment.

CITY01326

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SUMMARY OF ADDITIONAL ORGANIC CHEMICALS DETECTED BY
PURGEABLE HALO CARBONS AND AROMATICS ANALYSIS
ANALYZED BY THE DEPARTMENT OF HEALTH SERVICES SOUTHERN CALIF. BRANCH LAB SECTION
ALL VALUES ARE IN PARTS PER BILLION (µg/l)

		Constituent			
Date	Well	Methylene Chloride	1,1 dichloro-ethane	cis 1,2 dichloro-ethylene	Other
11-7-83	Newmark #1	-	-	-	0.7 (chloroform)
2-14-84	"	-	-	-	-
"	Newmark #3[2]	-	1.0	-	See Note 1
3-16-84	Newmark #3[3]	-	1.2	-	-
10-4-84[4]	Leroy	-	-	-	-
"	Newmark #2	-	-	-	-
"	Newmark #3	3.0	1.8	2.5	0.2 (1,1 dichloro-ethylene)
"	Newmark #1	0.5	0.48	0.37	-
1-22-85	Leroy	-	-	-	-
"	Newmark #3	3.9	1.9	3.1	-
"	Newmark #1	0.90	0.95	1.0	-
1-25-85	Newmark #3[5]	4.2	2.1	3.6	-

1 A non-quantifiable level of Dichlorofluromethane (Freon 21) was detected in all of these analyses except for the Newmark No. 1 samples collected on 11-7-83 and 2-14-84.

2,3 These values represent the maximum levels of various organics detected during special pumping tests.

4. Samples for base neutral and acid extractables were collected on this date for all four Newmark wells.

5 These values represent the maximum levels of the various organics detected during a packed tower aeration treatment pilot test program.

SUMMARY

RESULTS OF [illegible]E/PCE SAMPLES FROM THE DELMAN [illegible]TEM WELLS

ANALYZED BY THE DEPARTMENT OF HEALTH SERVICES SOUTHERN CALIFORNIA BRANCH LABORATORY SECTION

(EXCEPT WHERE NOTED *)

ALL VALUES ARE IN PARTS PER BILLION (μg/l)

Sampled	Darby		Colima		Gardena		State	
	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE
3/13/80	11	20	1.9	4.5	5.7	7.3	< .05	< .05
3/27/80	6.2	17	1.9	6.1	5.1	8.4	-	-
)/8/80	8.2	17	1.8	5.1	5.9	8.5	-	-
)/22/80	6.8	15	1.7	4.3	5.9	6.4	-	-
)/25/80 [1]	6.7	15	3.1	7.2	5.3	7.0	< .25	< .25
3/20/81	-	-	3.6	12.2	30	38	< .1	< .1
)/16/81	6.7	18	2.3	9.8	18	42	-	-
1/25/81	10	22	2.7	9.2	18	41	-	-
3/25/82	4.5	10.9	2.3	6.9	16.9	28.2	< .1	< .1
0/15/82	-	-	1.8	6.6	12	30	< .2	< .2
/13/83	5.1	9.5	1.0	3.8	9.5	19	-	-
2/1/83 *	2.6	8.7	-	-	8.2	28.1	< 1.0	< 1.0
3/10/83*	2.8	17.4	1.7	6.8	2.3	8.3	< 1.0	< 1.0
/9/84 *	-	-	1.5	6.7	-	-	-	-
[illegible]/84 *	2.0	9.9	< 1.0	3.4	3.3	9.1	< 1.0	1.0
[illegible] *	2.7	12.2	< 1.0	3.6	3.5	9.9	< 1.0	< 1.0
5/13/84*	1.9	12.9	< 1.0	2.4	1.2	6.9	< 1.0	< 1.0
5/24/84*	3.2	17.4	0.4	2.6	2.8	11.7	< .1	< 0.5
3/5/84 *	4.2	21.4	< 1.0	2.4	2.8	9.9	< 1.0	< 1.0
)/16/84*	3.7	18.3	1.3	2.1	2.5	8.1	< 1.0	< 1.0
'/20/85*	5.2	24.6	< .5	1.7	1.8	8.6	< .5	< .5
2/3/85 *	4.4	23.9	< .5	1.3	1.4	6.8	< .5	< .5
3/9/85 *	2.4	14	0.2	3.3	0.5	4.4	< .2	< .1

* Analyzed by California Water Labs

1. An analysis for Purgeable Halocarbons and Aromatics was performed by the Department of Health Services Sanitation and Radiation Lab in Berkeley on samples collected from the State and Darby wells. No organics were detected in the State well sample. A level of 7.4 TCE and 16.4 PCE was reported for the Darby well sample.

CITY01328

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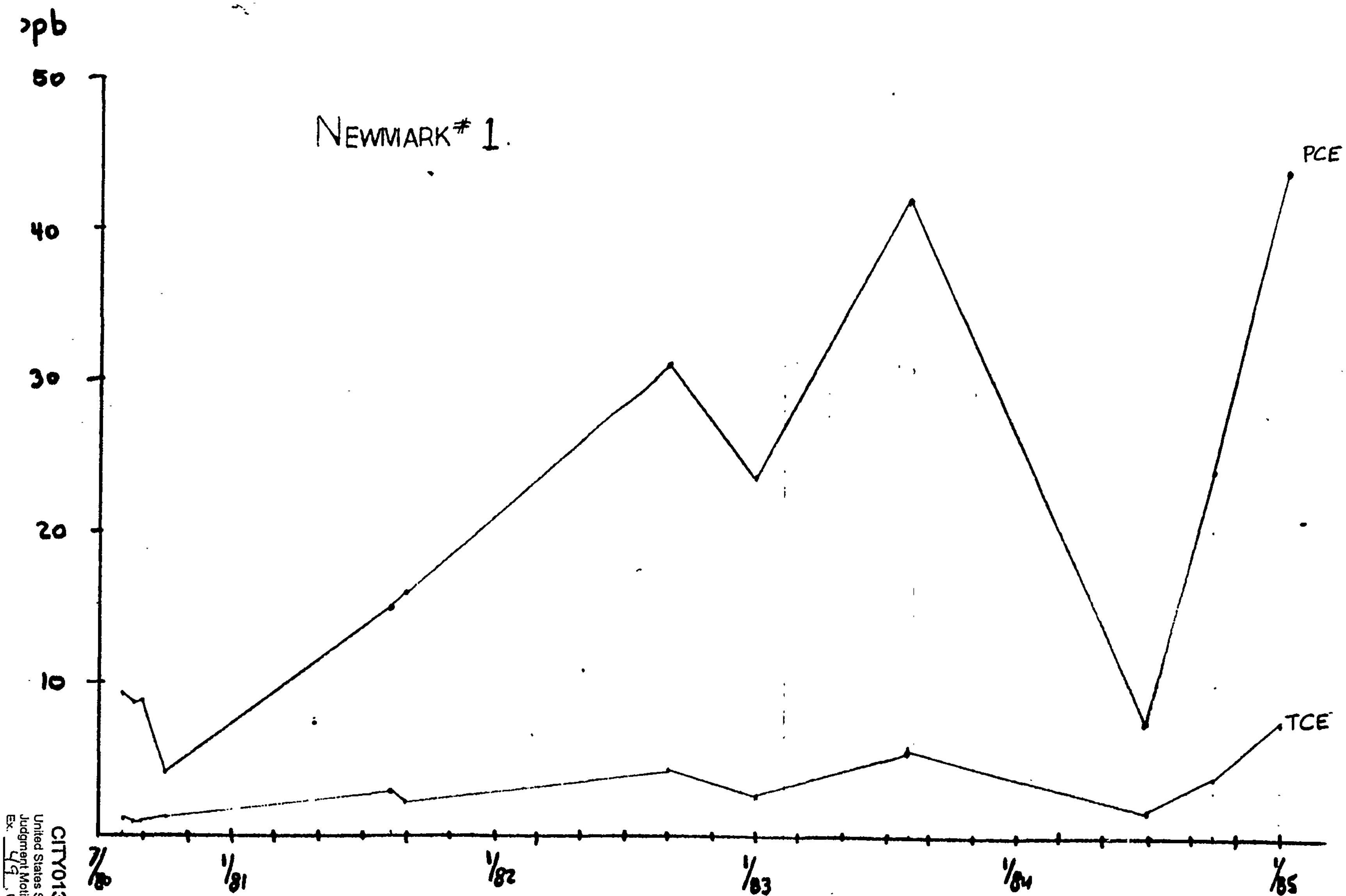

CITY01329
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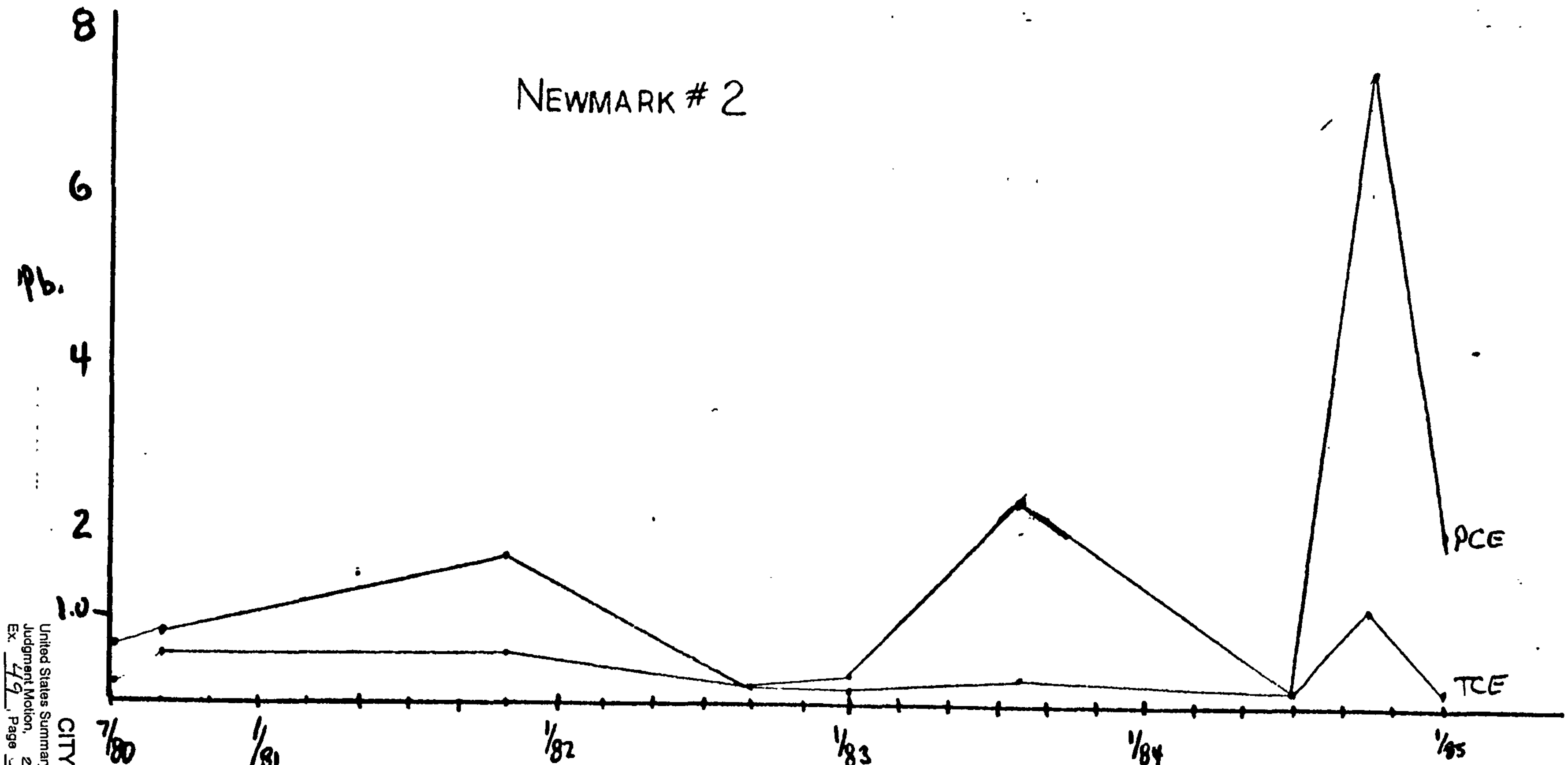
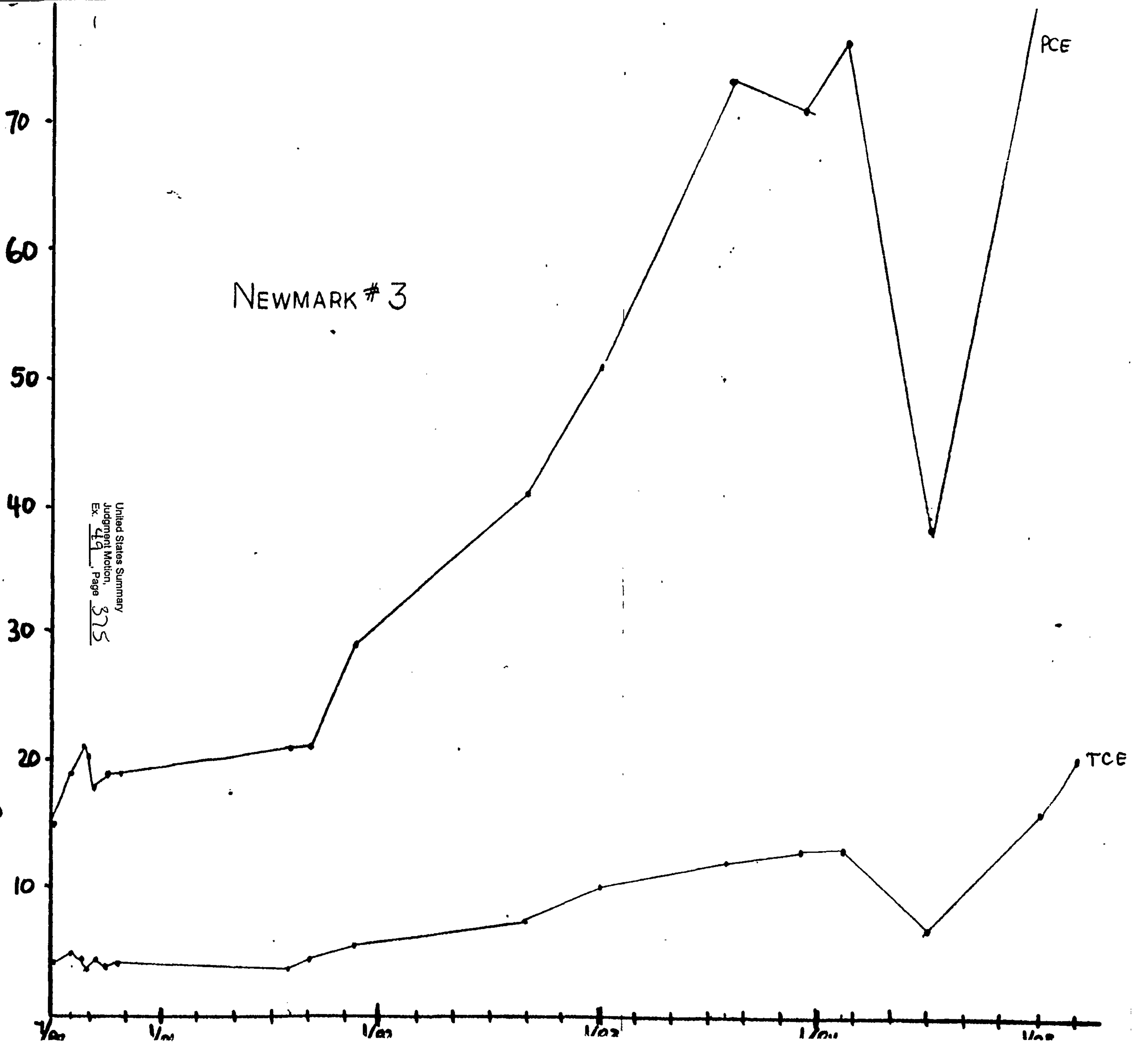

NEWMARK # 2
pb.
8
6
4
2
1.0
7/80
1/81
1/82
1/83
1/84
1/85
PCE
TCE



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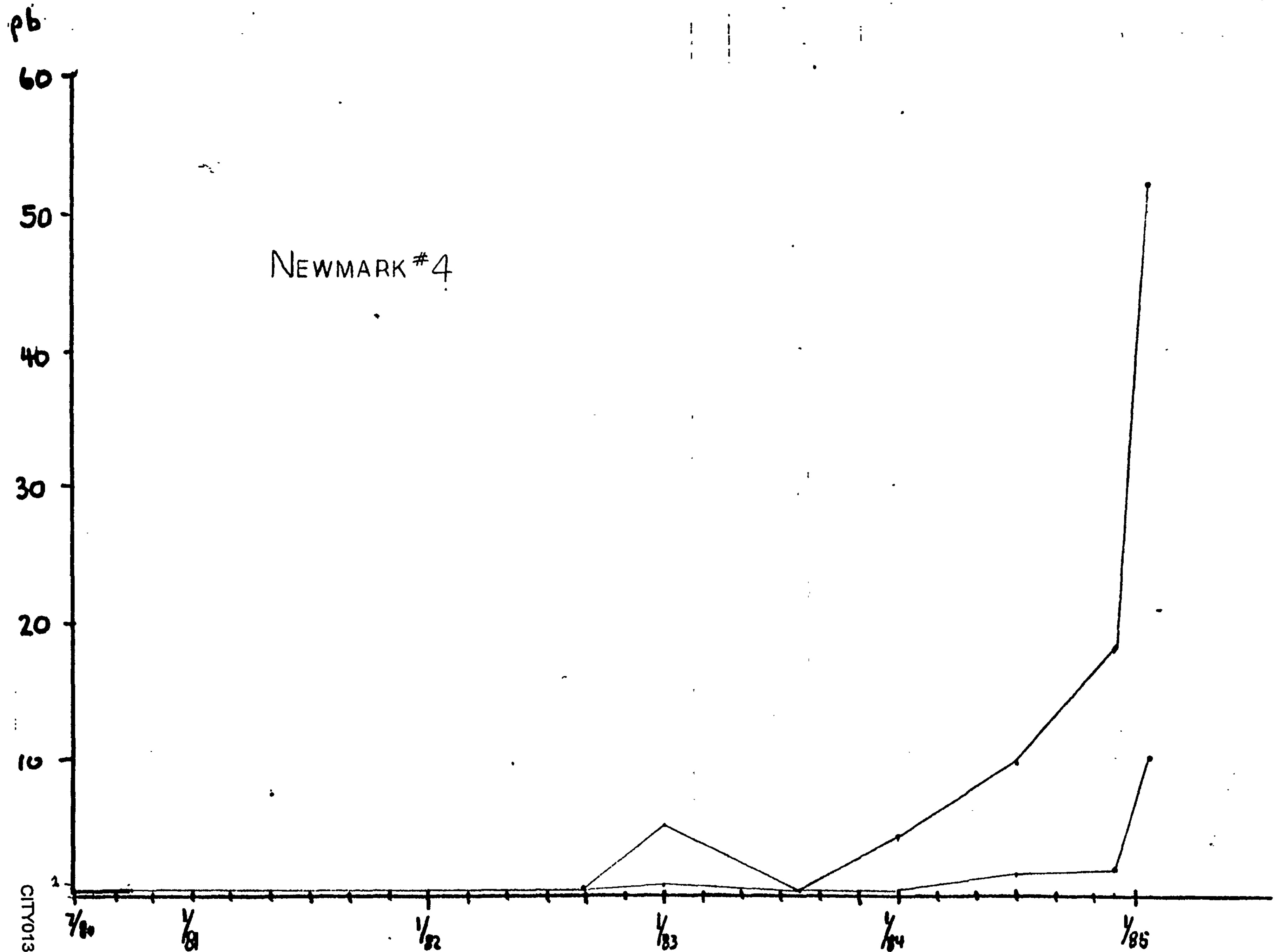
CITY01331



CITY01332

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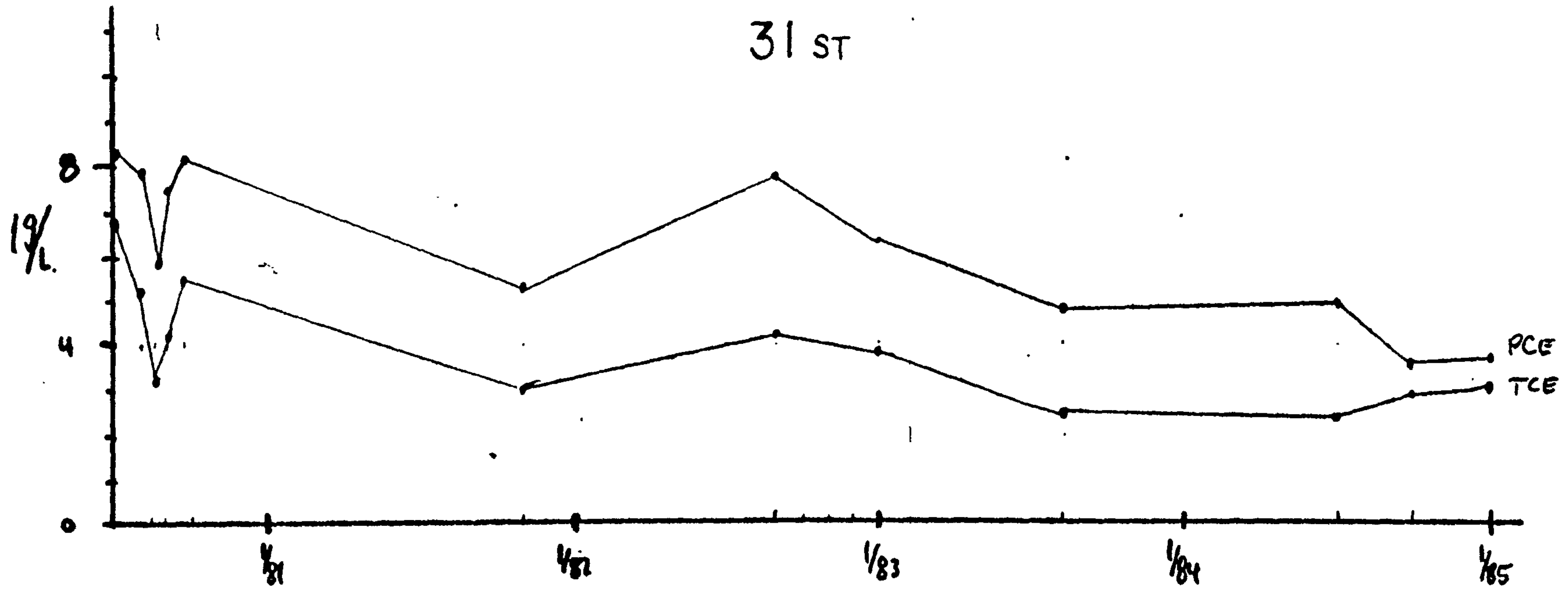
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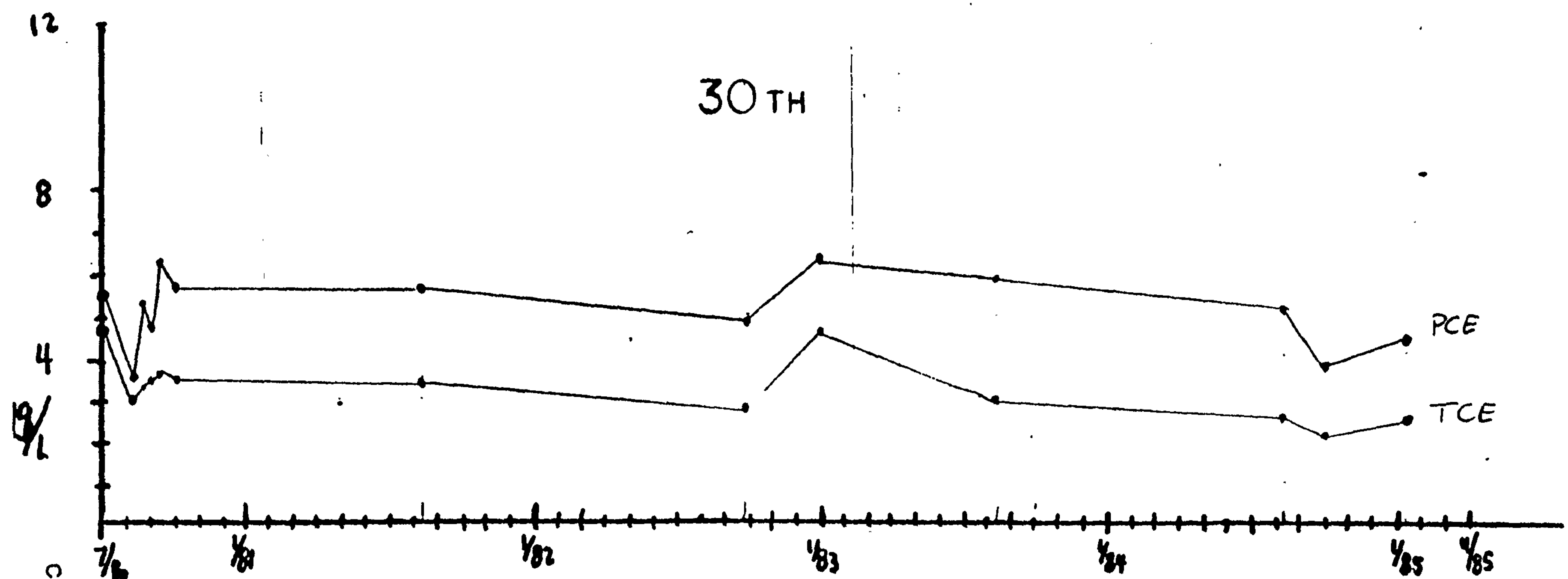
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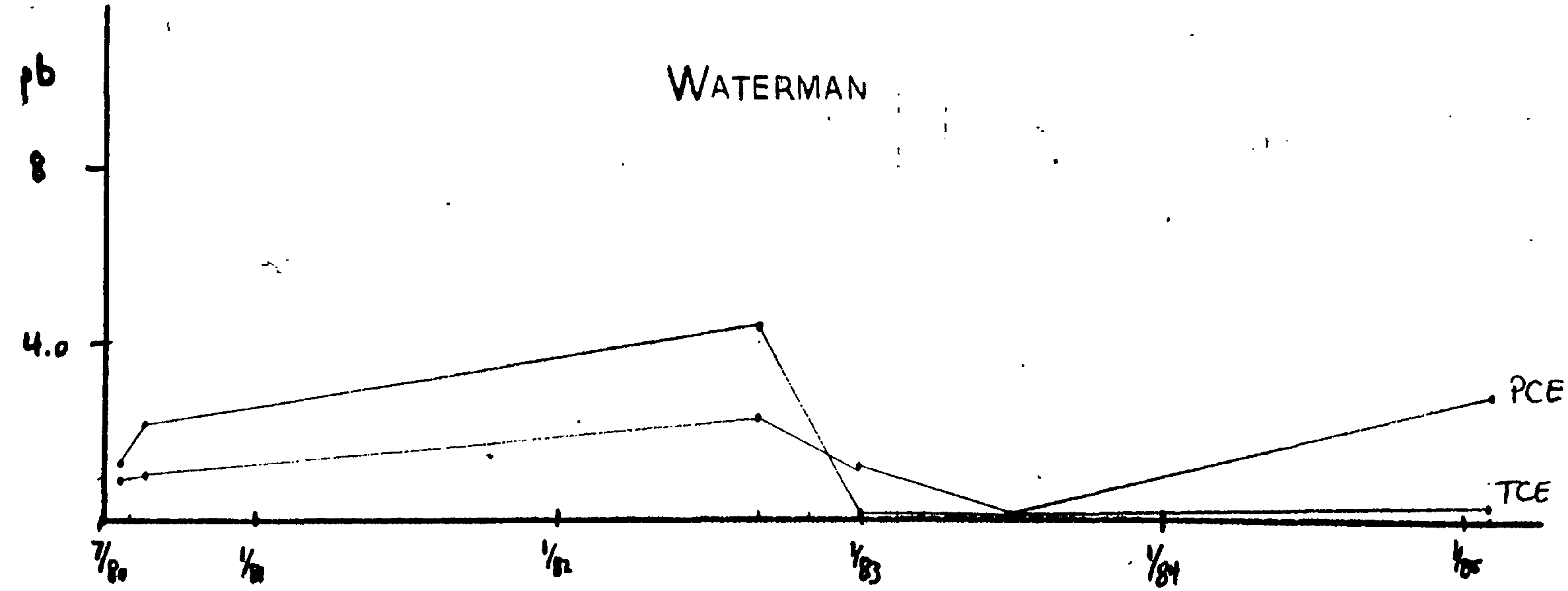

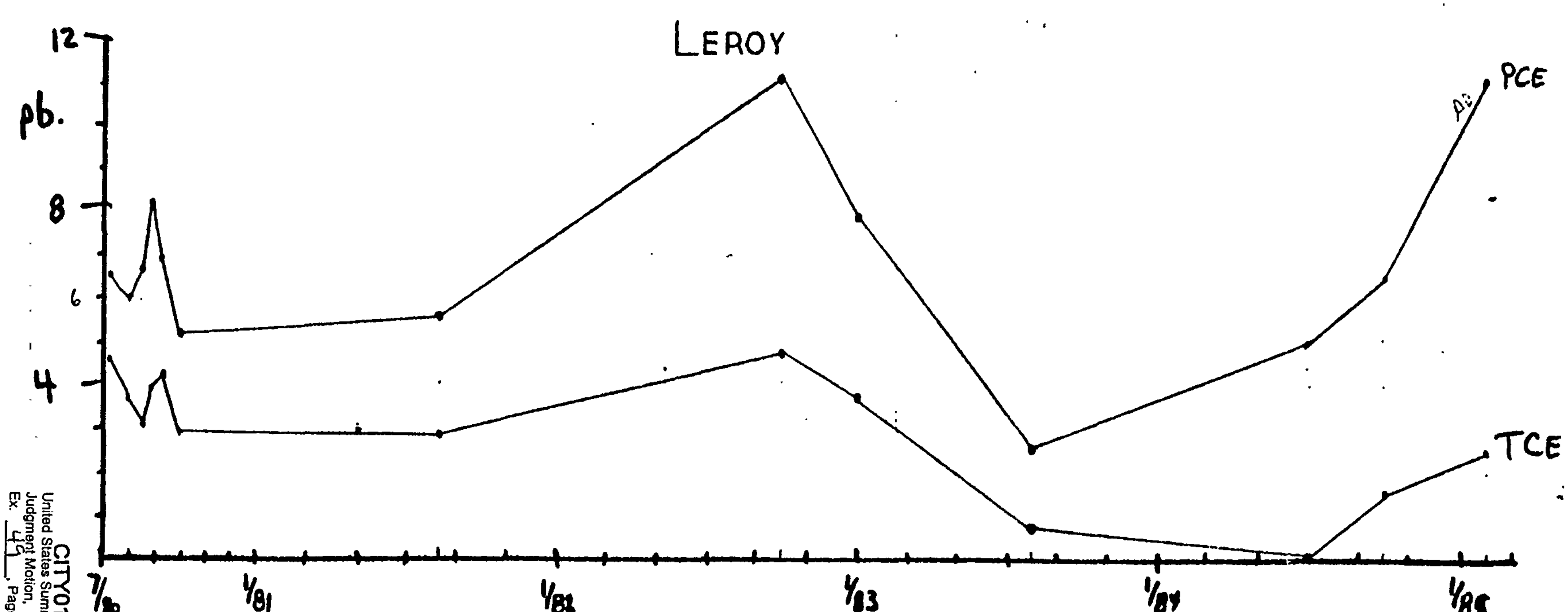

CITY01334
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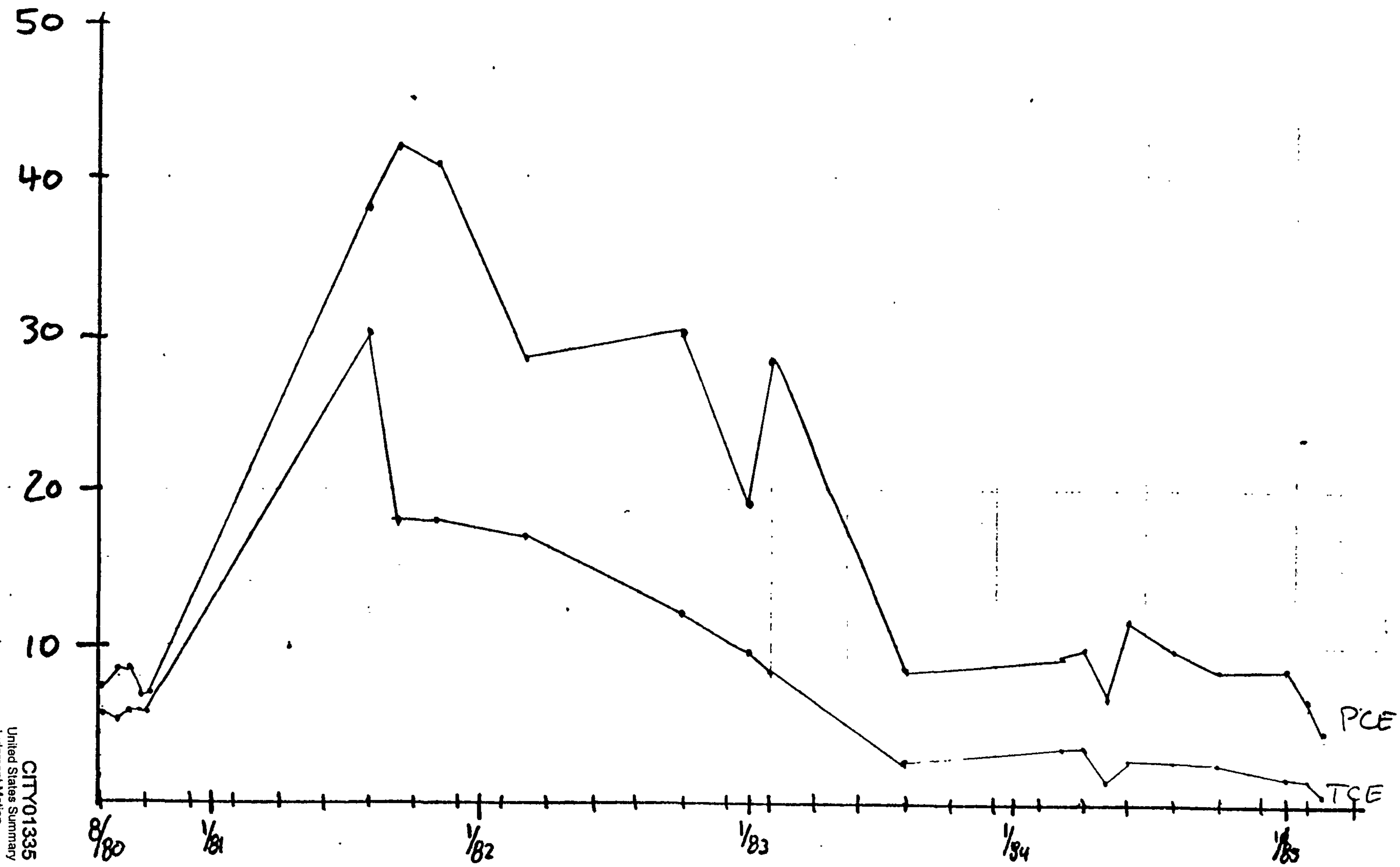
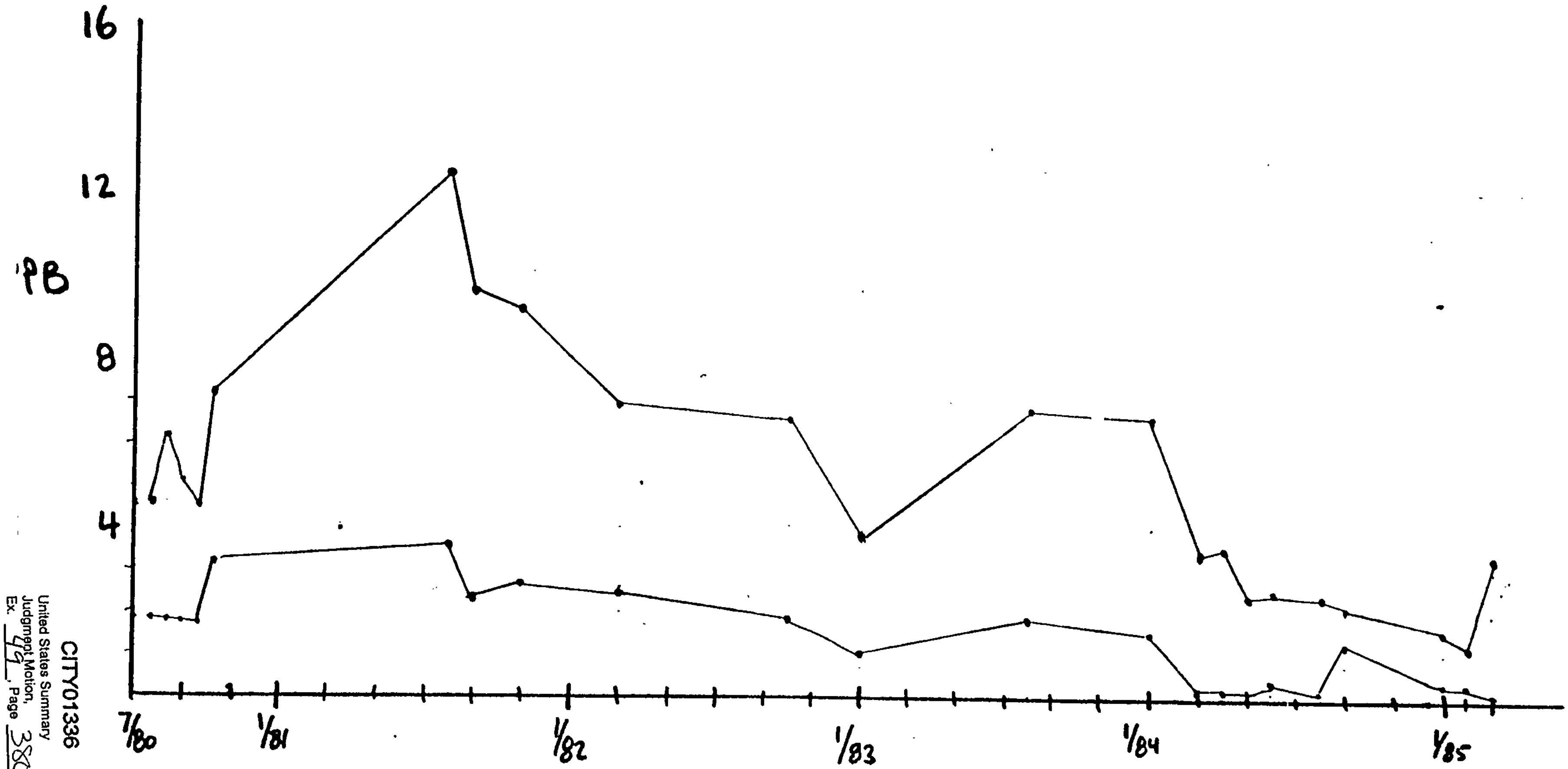
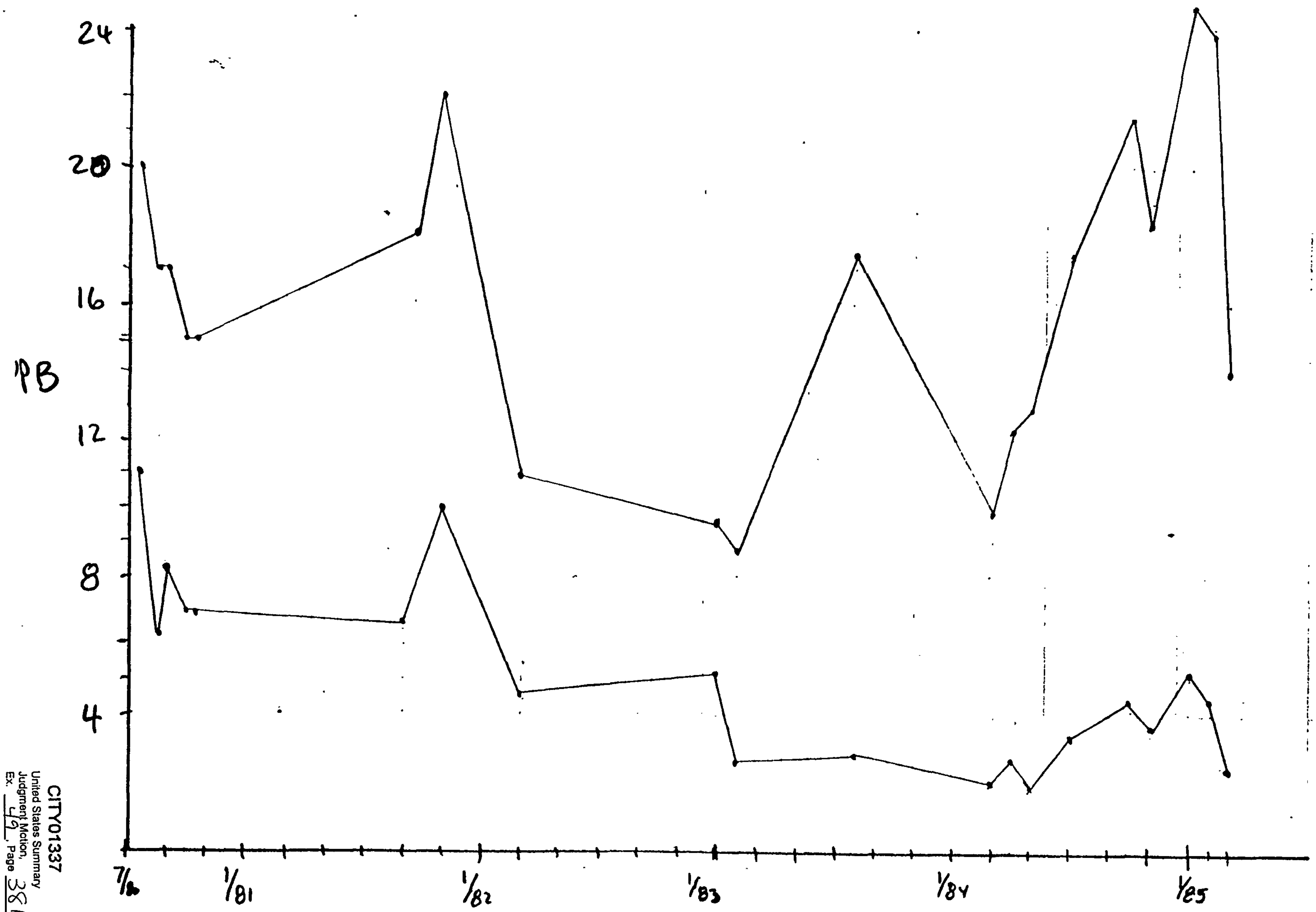
Gardena Well.



Colima Well



Darby well



CITY01337
United States Summary Judgment Motion, Ex. 49, Page 381

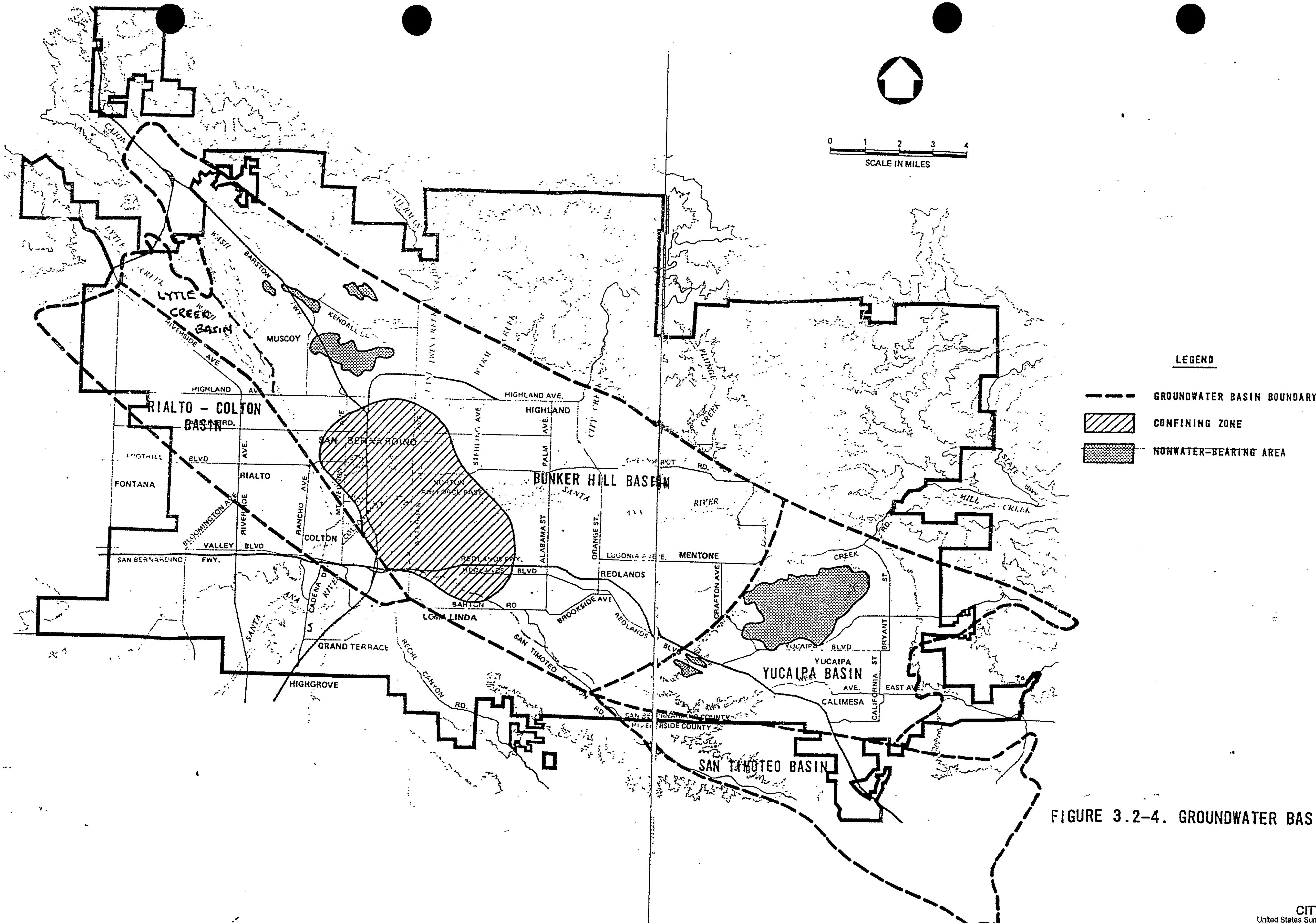


FIGURE 3.2-4. GROUNDWATER BASINS

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Diagram of Newma[illegible] Wells Showing Location of Perf[illegible]tions

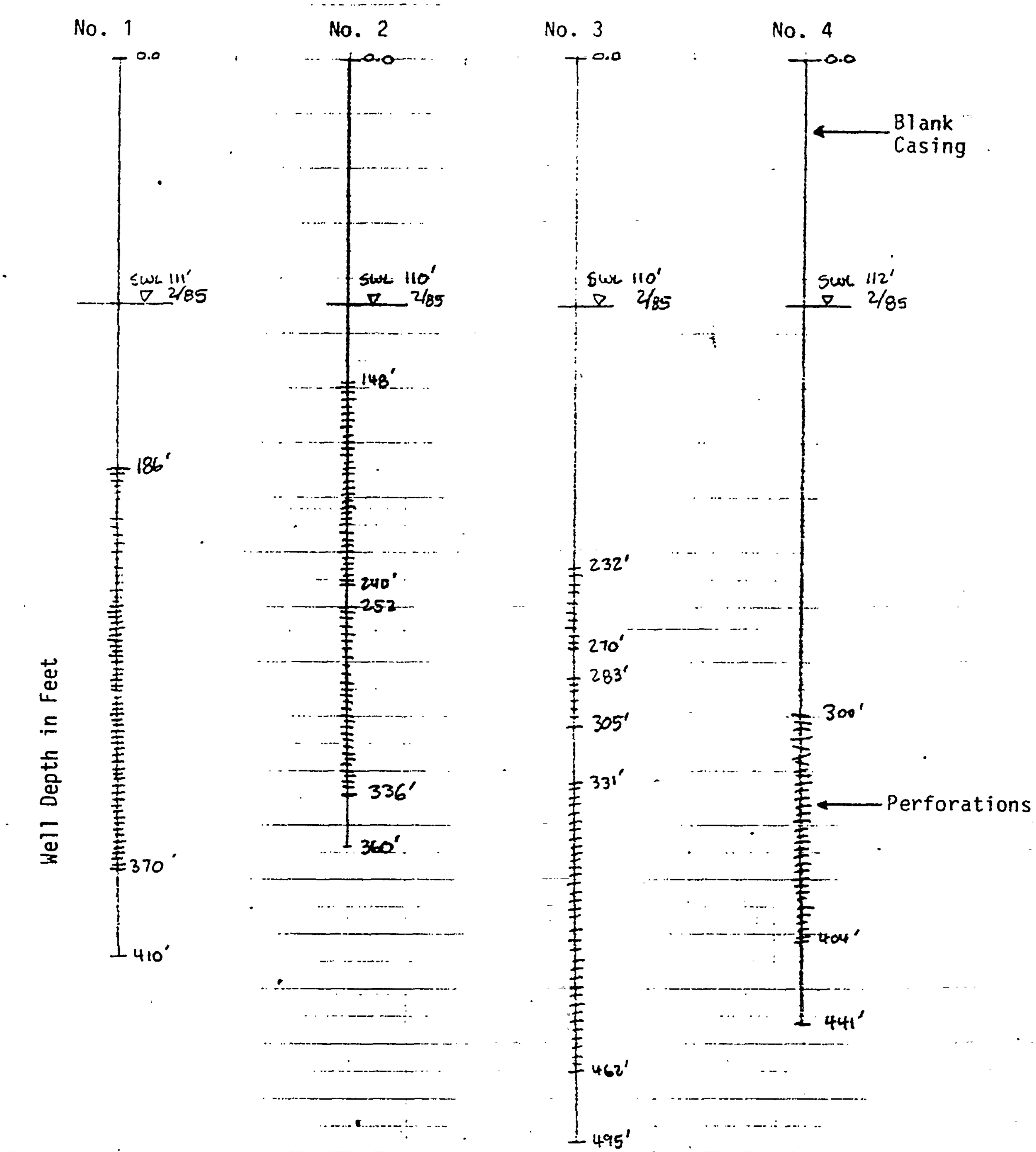

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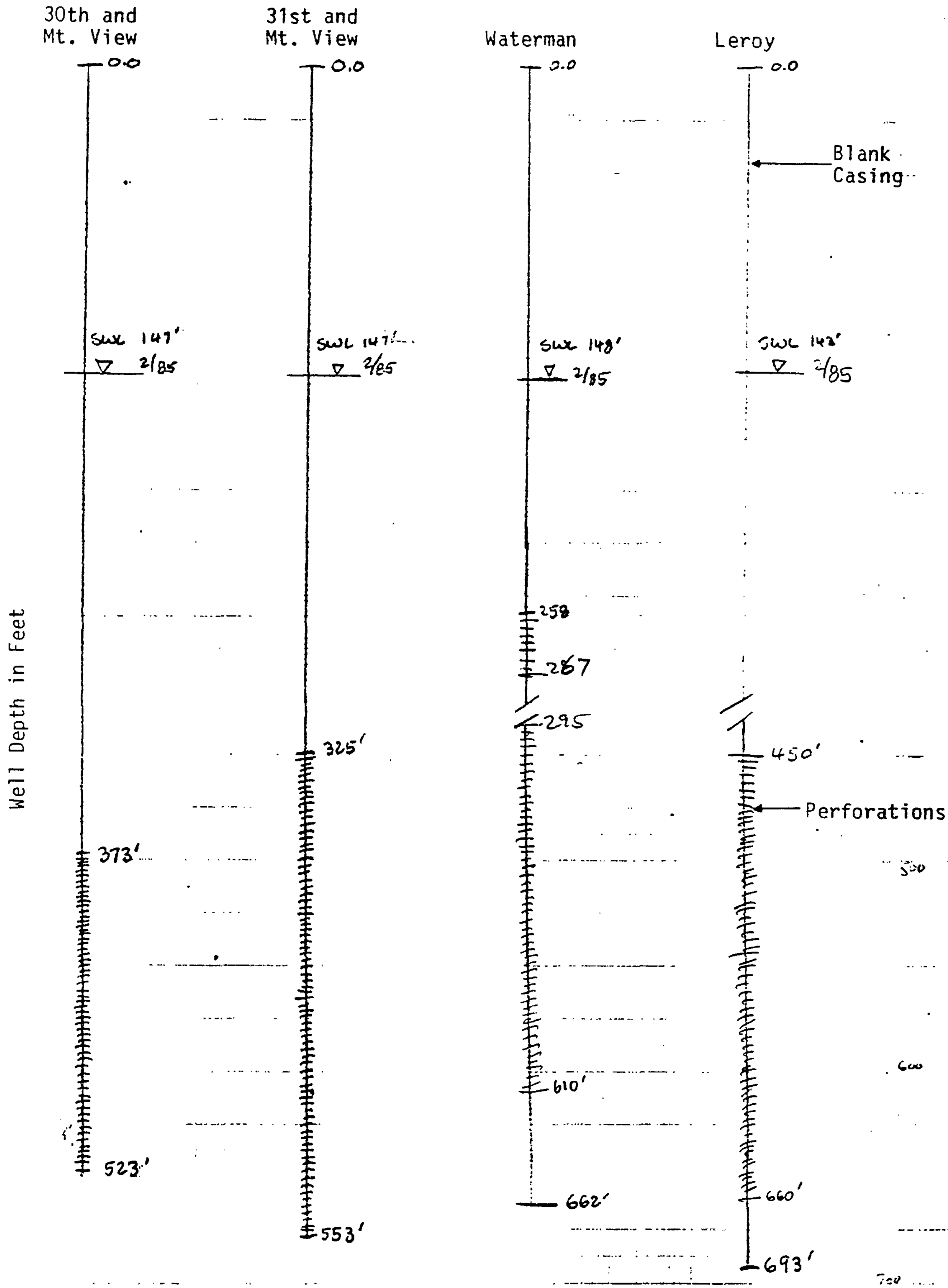
Diagram of City Wells Showing Location of Perforations



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CITY01340

STATE #E-10
WATER DEPT. #27

SAN BERNARDINO WATER DEPT. - NEWMARK WELL.

Northeast Corner of "A" Street and Western Avenue.
Arrowhead Suburban Farms.

Diameter 26-inches to 233-ft., Reduced to 12-inches.
Cement Joint Between 223-ft. to 235-ft.

0	Ft.	to	80	Ft.	Shaft.
80	Ft.	to	150	Ft.	Gravel and Boulders Cemented.
150	Ft.	to	180	Ft.	Gravel Coarse Cemented.
180	Ft.	to	186	Ft.	Clay Yellow.
186	Ft.	to	251	Ft.	Sand & Gravel -Loose, perforated.
251	Ft.	to	265	Ft.	Sandy & Clay -Loose, perforated.
265	Ft.	to	406	Ft.	Sand & Gravel -Loose, perforated.
406	Ft.	to	415	Ft.	Bedrock (Schist.)

Water Stands 88-ft. from surface.

Hole torn in Casing at 115-ft. from surface in 26-inch Casing.

June 22, 1966

Cleaned approximately 40.0' of sand from Well -
Sounded to depth - 413 Feet.

Used 13½" Swedge to flare 12" casing at 222.0' to protect Submersible Cable.

26" Casing separated at 160.0' on West side of Well.

Submersible Cable to be secured to East side of Pump Column to protect cable. - - - - - L. E. Maloy

STATE #E-10b

SAN BERNARDINO WATER DEPARTMENT

NEWMARK WELL NO. 2

175.0' South of Reservoir Drive, 40.0' West of Magnolia Drive, 300.0' East of Well #E-10.

Depth - 359.5'
Diameter - 20 Inches
Drilled - June, 1946
Drilled By - E. W. Brockman & Son

0	Ft.	to	20 Ft.	Sand and Gravel
20	Ft.	to	110 Ft.	Cemented Gravel and Boulders.
110	Ft.	to	112 Ft.	Loose Rock
112	Ft.	to	148 Ft.	Cemented Sand - Coarse.
148	Ft.	to	198 Ft.	Coarse Sand and Gravel.
198	Ft.	to	204 Ft.	Sand and Gravel with Clay.
204	Ft.	to	240 Ft.	Sand and Gravel
240	Ft.	to	252 Ft.	Dirty Sand
252	Ft.	to	336 Ft.	Cemented Sand and Gravel
336	Ft.	to	340 Ft.	Gravelly Clay and Boulders.
340	Ft.	to	359½ Ft.	Hill Formation

Perforated at

148 Ft. to 240 Ft.

252 Ft. to 336 Ft.

8 Cuts per Round every 12" - 7/16" Mills Blade

STATE #E-10c

NEWMARK WELL NO. 3

283.0 feet East ℄ of Western Avenue - 94.0 feet
North ℄ of 42nd. Street.

Diameter - 16 Inches
8 Gage Double Casing
Depth - 495 Feet
Drilled - May, 1954
Drilled By - John R. Beylik

0	Ft.	to	10	Ft.	Sand and Gravel
10	Ft.	to	20	Ft.	Sand and Gravel (coarse)
20	Ft.	to	30	Ft.	Gravel and Boulders
30	Ft.	to	130	Ft.	Sand, Gravel and Boulders
130	Ft.	to	160	Ft.	Cemented Sand and Gravel (coarse)
160	Ft.	to	170	Ft.	Cemented Sand with Clay and Gravel
170	Ft.	to	180	Ft.	Sand and Gravel (coarse)
180	Ft.	to	200	Ft.	Sandy Clay and Gravel
200	Ft.	to	212	Ft.	Sand and Gravel, loose Boulders
212	Ft.	to	214	Ft.	Sandy Clay
214	Ft.	to	230	Ft.	Sand and Gravel
230	Ft.	to	232	Ft.	Sandy Clay
232	Ft.	to	242	Ft.	Coarse Gravel and Boulders
242	Ft.	to	253	Ft.	Sandy Clay and Gravel, Boulders
253	Ft.	to	256	Ft.	Hard Sandy Clay
256	Ft.	to	260	Ft.	Sand, Coarse Gravel, loose Boulders
260	Ft.	to	262	Ft.	Hard Sandy Clay
262	Ft.	to	270	Ft.	Coarse Gravel, Boulders
270	Ft.	to	283	Ft.	Fine Sand
283	Ft.	to	305	Ft.	Coarse Gravel, loose Boulders
305	Ft.	to	306	Ft.	Hard Sandy Clay

NEWMARK WELL NO. 3

(Continued)

306	Ft.	to	330 Ft.	Fine Sand and Gravel
330	Ft.	to	331 Ft.	Sandy Clay
331	Ft.	to	381 Ft.	Fine Sand and Gravel loose Boulders
381	Ft.	to	462 Ft.	Coarse Gravel and Boulders
462	Ft.	to	475 Ft.	Hard Sandy Clay (red)
475	Ft.	to	495 Ft.	Schist - Bedrock

Static Water Level - May 10, 1954 - 191.5'

1,475 G. P. M. - Pumping Level - May 12, 1954 - 207.2'

Temperature - 66°

Perforated with a Mills Knife with a 7/16" Blade - 8 Cuts to a Circle on 12" Centers.

Perforated

232-ft. to 270-ft.
283-ft. to 305-ft.
331-ft. to 462-ft.

Casing Ends at 480-ft. - Open Hole to 490-ft.

STATE SERIAL #E-10e
STATE WELL NUMBER 01N/04W-16E04,S

NEWMARK WELL NO. 4

65.0 feet West ℄ of Reservoir Drive - 50.0 feet East ℄ of Western Avenue

Diameter - 20 Inches
6 Gage Casing - Double
Depth - 441 Feet
Drilled - April, 1967
Drilled By - Russell H. Forney

0	Ft.	to	2 Ft.	Top Soil
2	Ft.	to	35 Ft.	Gravel 0-6" and some Clay
35	Ft.	to	40 Ft.	Gravel and Boulders - Loose
40	Ft.	to	189 Ft.	Loose Gravel 0-3" some Clay
189	Ft.	to	203 Ft.	Light Brown Sandy Clay
203	Ft.	to	205 Ft.	Gravel and Boulders
205	Ft.	to	223 Ft.	0-3" Gravel and Clay
223	Ft.	to	249 Ft.	Clean loose Gravel 0-2"
249	Ft.	to	276 Ft.	Clay and Gravel 0-2"
276	Ft.	to	311 Ft.	Gravel, some Clay 0-2"
311	Ft.	to	386 Ft.	Loose Gravel Boulders - some Clay
386	Ft.	to	390 Ft.	Yellow Clay Decomposed Granite
390	Ft.	to	398 Ft.	Granite fairly Hard, some Yellow Clay
398	Ft.	to	426 Ft.	Decomposed Granite, some Yellow Clay
426	Ft.	to	441 Ft.	Blue Granite Rocks fairly Hard

Static Water Level - April 18, 1967 - 265.0'

2,550 G. P. M. - Pumping Level - 293.0'

Perforated with Mills Mechanical Knife

3/8" X 3½" Blade

Perforations

300-ft. to 404-ft. - 12 Cuts @ L

STATE #E-25g
WATER DEPT. #192

SAN BERNARDINO WATER DEPT. - 30TH & MT. VIEW WELL
(MARSHALL WELL)

Northeast Corner of 30th and Mt. View Streets, San Bernardino.

1926.

20-inch Diameter.

0	Ft.	to	104	Ft.		Shaft to Water.
104	Ft.	to	523	Ft.		Gravel.

Bottom 150-ft. is all that has been cut.

STATE #E-0025L

31ST. AND MT. VIEW AVENUE WELL

35.0 feet West ℄ North Bound Lane of Mt. View Avenue and 30.0 feet South ℄ of 31st. Street.

Diameter - 20 Inches
6 Gage Casing - Double
Depth - 577 Feet
Drilled - December, 1962
Drilled By - Ray Roberts Pumps and Equipment

0	Ft.	to	60 Ft.	Sand
60	Ft.	to	72 Ft.	Sand and Pea Gravel
72	Ft.	to	102 Ft.	Sand
102	Ft.	to	224 Ft.	Sand and Gravel
224	Ft.	to	242 Ft.	Tight Pea Gravel
242	Ft.	to	281 Ft.	Gravel up to 5 inches
281	Ft.	to	289 Ft.	Red Sand
289	Ft.	to	303 Ft.	Sand Gravel and Streaks of Clay
	Ft.	to	319 Ft.	Sand Clay and Gravel
319	Ft.	to	491 Ft.	Gravel, Clay and Sand Some 6" Gravel
491	Ft.	to	553 Ft.	Gravel up to 12 inches
553	Ft.	to	577 Ft.	Clay and Hill Formation, Decomposed Material

Static Water Level - December 17, 1962 - 251.0 feet

3,700 G. P. M.

Pumping Level - December 18, 1962 - 278.5 feet

Temperature - 66°

Perforated with Mills Mechanical Knife

Cut 1/2" X 3½" - 9 Cuts to 12"

<u>Perforations</u>

325-ft. to 553-ft.

STATE #E-35w

WATERMAN AVENUE WELL

300-ft. South of Marshall Blvd. and 270-ft. West of Waterman Avenue.

Diameter	-	20 Inches 6 Gage Casing
Depth	-	662 Feet
Drilled	-	November, 1949.
Drilled By	-	Barber-Bridge

0	Ft.	to	8	Ft.	Top Soil Sandy
8	Ft.	to	62	Ft.	Clay Sandy
62	Ft.	to	238	Ft.	Gravel to 6"
238	Ft.	to	258	Ft.	Gravel to 6" Clay Streaks
258	Ft.	to	267	Ft.	Gravel to 3"
267	Ft.	to	295	Ft.	Gravel to 3"- Clay
295	Ft.	to	438	Ft.	Gravel to 4"
438	Ft.	to	490	Ft.	Gravel and Boulders
490	Ft.	to	542	Ft.	Gravel and Boulders, Tight
542	Ft.	to	594	Ft.	Gravel and Boulders
594	Ft.	to	636	Ft.	Gravel and Boulders, Tight
636	Ft.	to	658	Ft.	Cemented Gravel
658	Ft.	to	662	Ft.	Clay Red Sandy

Bottom shoe at 638-ft. - inserted 18" X 5/16" X 36.0' Perforated Liner in bottom of Well.
Test show maximum of 3,960 G.P.M. - Total head 163.0'
Drawdown = 17.0'

For Details - See Field Book #48 - Pg. 7

Perforated 258-ft. to 267-ft.
295-ft. to 610-ft.

Hydraulic Perforator

7/16" X 3" Hole
8 Holes at 12" Center Line

S[illegible]E #E-435a

LEROY STREET WELL

80.0 feet East ℄ of LeRoy Street - 576.0 feet South ℄ of Marshall Boulevard

Diameter - 20 Inches
6 Gage Casing - Double
Depth - 693 Feet
Drilled - August, 1967
Drilled By - Russell H. Forney

0	Ft.	to	3	Ft.	Top Soil
3	Ft.	to	63	Ft.	Sand some Gravel 2"
63	Ft.	to	113	Ft.	Gravel 3" some Brown Clay
113	Ft.	to	120	Ft.	Pea Gravel
120	Ft.	to	134	Ft.	Gravel Tight 4"
134	Ft.	to	151	Ft.	Gravel 3" Loose
151	Ft.	to	172	Ft.	Brown Silty Clay
172	Ft.	to	237	Ft.	Gravel 2" Loose
237	Ft.	to	303	Ft.	Gravel 3" Red Clay 75%
303	Ft.	to	308	Ft.	Gravel 2" Loose
308	Ft.	to	328	Ft.	Gravel 4" some Clay Tig
328	Ft.	to	338	Ft.	Gravel 4" Loose Clean
338	Ft.	to	358	Ft.	Coarse Sand 90% Gravel some Clay
358	Ft.	to	373	Ft.	Gravel 3" some Clay
373	Ft.	to	397	Ft.	Gravel and Boulders Tigh
397	Ft.	to	457	Ft.	Gravel 4" some Blue Cla Tight
457	Ft.	to	573	Ft.	Loose Gravel 4"
573	Ft.	to	576	Ft.	Gravel 4" Decomposed Granite 50%
576	Ft.	to	632	Ft.	Gravel 8" Tight
632	Ft.	to	664	Ft.	Gravel Cemented some Blue Clay
664	Ft.	to	669	Ft.	Blue Clay
669	Ft.	to	692	Ft.	Shale Blue and Brown

Static Water Level - July 30, 1967 - 304.0'

3,700 G. P. M. - Pumping Level - 330.0'

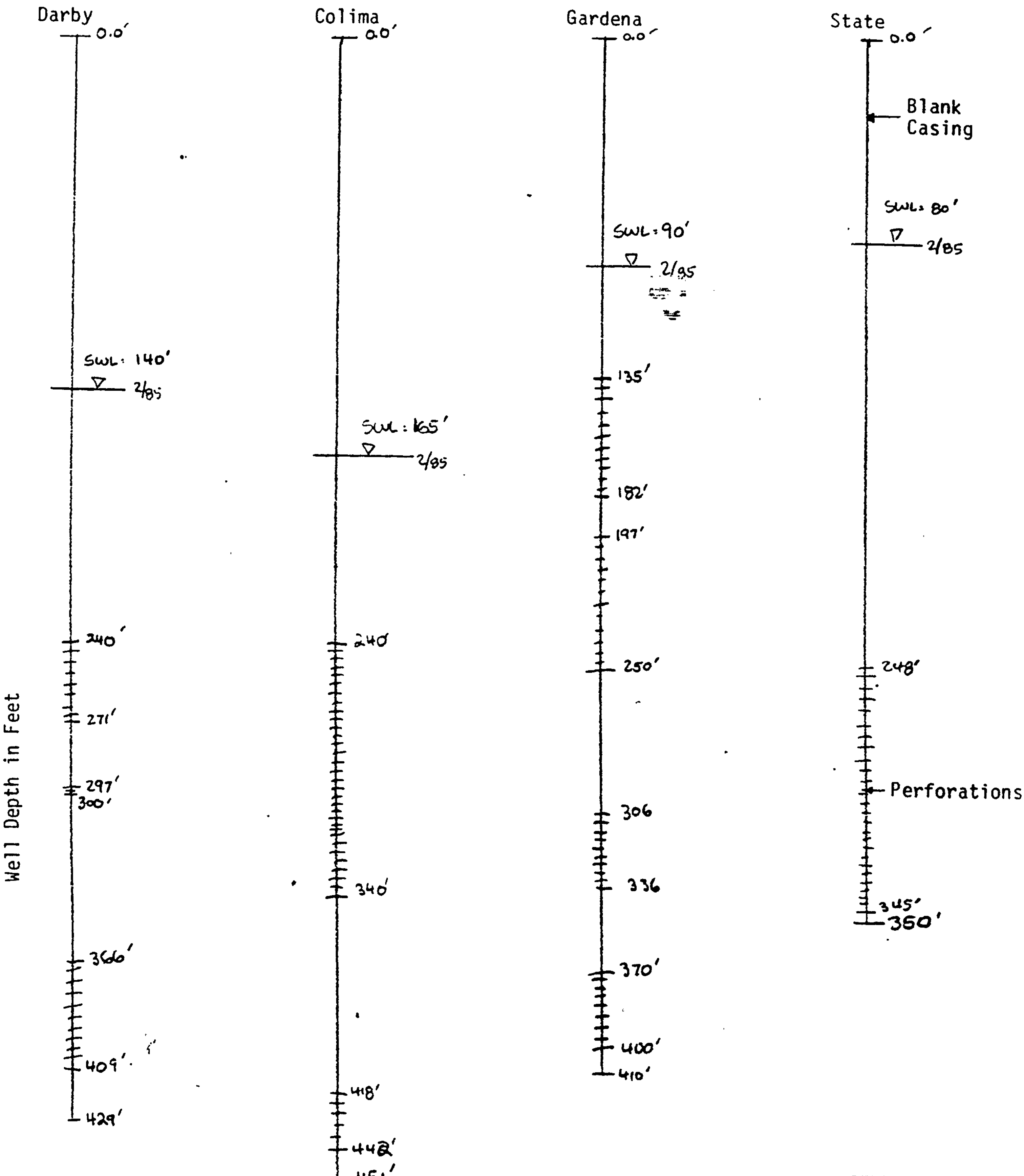
Temperature - 64°

Perforated with Mills Mechanical Knife

3/8" X 3½" Blade

<u>Perforations</u>

450-ft. to 660-ft. - 12 Cuts @ 12" ℄


Darby
0.0'
SWL: 140'
2/85
240'
271'
297'
300'
366'
409'
429'
Colima
0.0'
SWL: 165'
2/85
240'
340'
418'
442'
451'
Gardena
0.0'
SWL: 90'
2/85
135'
182'
197'
250'
306
336
370'
400'
410'
State
0.0'
Blank Casing
SWL: 80'
2/85
248'
Perforations
345'
350'
Well Depth in Feet

CITY01350

WELL LOGS

COLIMA WELL

- 155'	Gravel & boulders
- 163	Hard red clay
163 - 210	Gravel & boulders
210 - 245	Loose gravel 2"
245 - 251	Clay & Gravel 1"
251 - 283	Loose Gravel 1"
283 - 293	Sandy bround clay
293 - 303	Sand some gravel 1/2"
303 - 334	Loose gravel 2"
334 - 371	Sandy yellow clay
371 - 380	Sand some clay done't cut
380 - 390	Brown sandy clay
390 - 408	Sand & clay some fine gravel
408 - 418	Sandy brown clay
418 - 429	Sand, gravel & clay
429 - 447	Loose gravel 2"
447 - 451	Yellow sandy clay

WATER LEVELS: 1956
Depth Found 220'
Stand. Level 220' (before perforating)
" " 220' (after ")

PERFORATIONS
Perforator type - Mills
Size of perforations 5/16" length by 2 - 3/4"

From ft.	to Ft.	Perf. per row	rows per ft.
[illegible]	340'	8	1
[illegible]	442	8	1

Casing installed - New Well, Domestic
0 Ft to 451 Ft, Diam 16" - Gage of Wall 10"
Type and size of shoe or well ring, 16"x12"x1"
Describe joint - Spot welded

GARDENA WELL

Drilled 1929 - 12" casing
Depth 410'

Perforated	
135' to 182'	47'
197' to 250'	53'
306' to 336'	30'
370' to 400'	30'
Total	100'

Water level Feb 1953 172'

DARBY WELL

Diameter - 16"
Depth - 429'

0 - 156'	Sand & Gravel
156 - 270.5	Gravel
270.5 - 271	Clay
271 - 272	Gravel
275 - 276	Clay
276 - 297	Fine sand
297 - 309	Gravel
309 - 310	Clay
310 - 314	Gravel
314 - 354	Clay
354 - 380	Gravel
380 - 387	Quicksand
387 - 405	Gravel
- 409	Sand
- 429	Gravel

PERFORATED - 3 cuts every 5'
240' to 271'
297' to 300'
366' to 380'
393' to 403'

Only coarse gravel cut

Water level - April 20, 1950 - 185.4'

WELL LOG

Well drilled by two drillers

1st Phase (Rotary)	(Evans Bros.)	Cemented 68' of 3/8"x20" casing in 24" hole
0 - 37	sand and boulders	
47 - 40	clay	Set 120' of 3/16"x16" casing in 20" hole; packed with 4 1/2 tons #3 gravel.
40 - 65	sand and boulders	
65 - 72	clay	
72 - 75	boulders	
75 - 85	clay	Hole drilled to 125'
85 - 92	boulders	Casing stopped on boulder at 120'
92 - 96	clay	Perforated 68' - 128'
96 - 120	small boulders	
120 - 125	granite boulders	
2nd Phase (Cable)	(By Mogle Brothers)	
0 - 126	in abandoned well	Perforated 3/8" x 2" 248' - 345'
126 - 135	dry gravel	
135 - 150	sand	Gravel packed
150 - 164	quicksand	
164 - 174	rock & gravel	Completed 4-18-51
174 - 234	coarse sand	
234 - 350	gravel	350' 12" dble 12 ga casing

CITY01352

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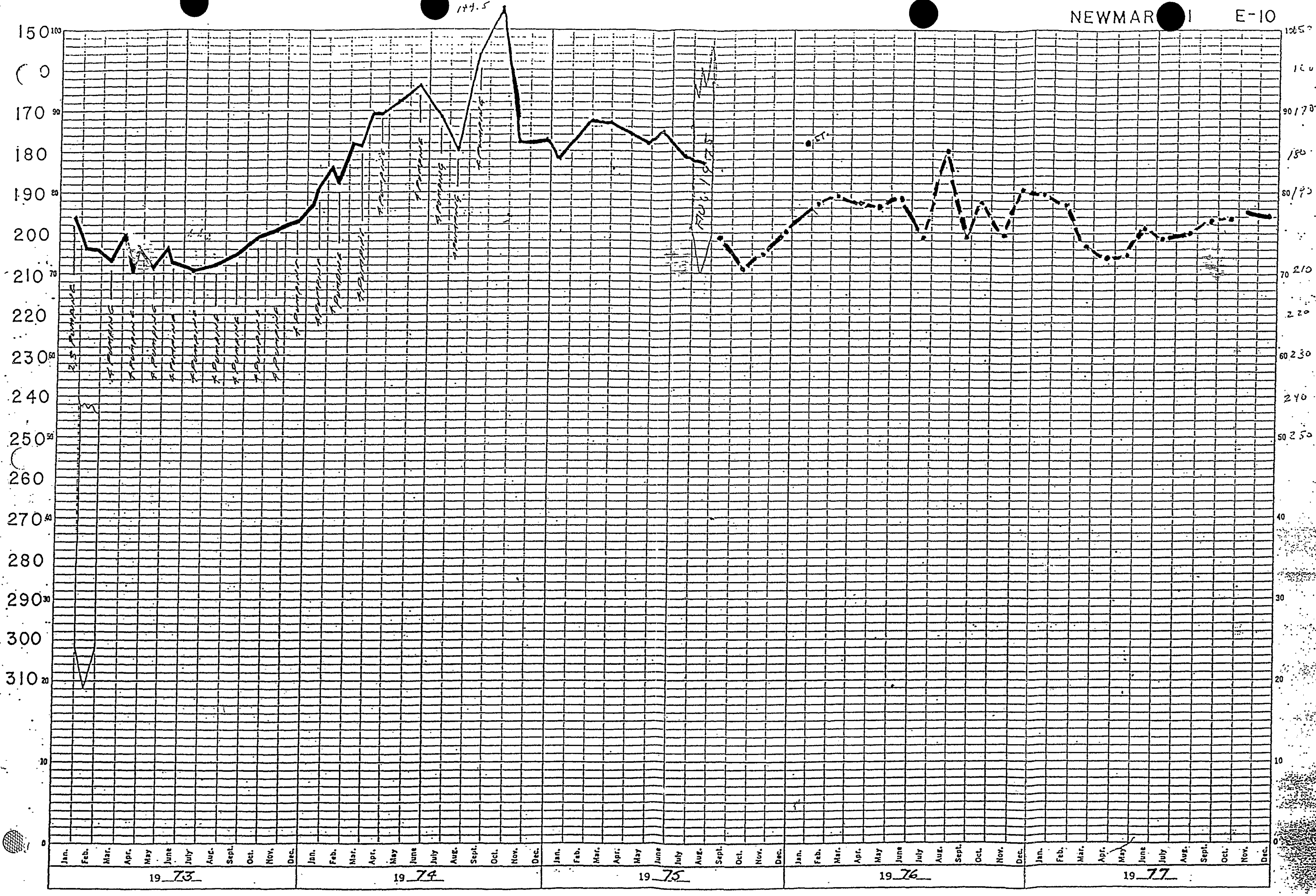
NEWMAR[illegible]I E-10



CITY01353

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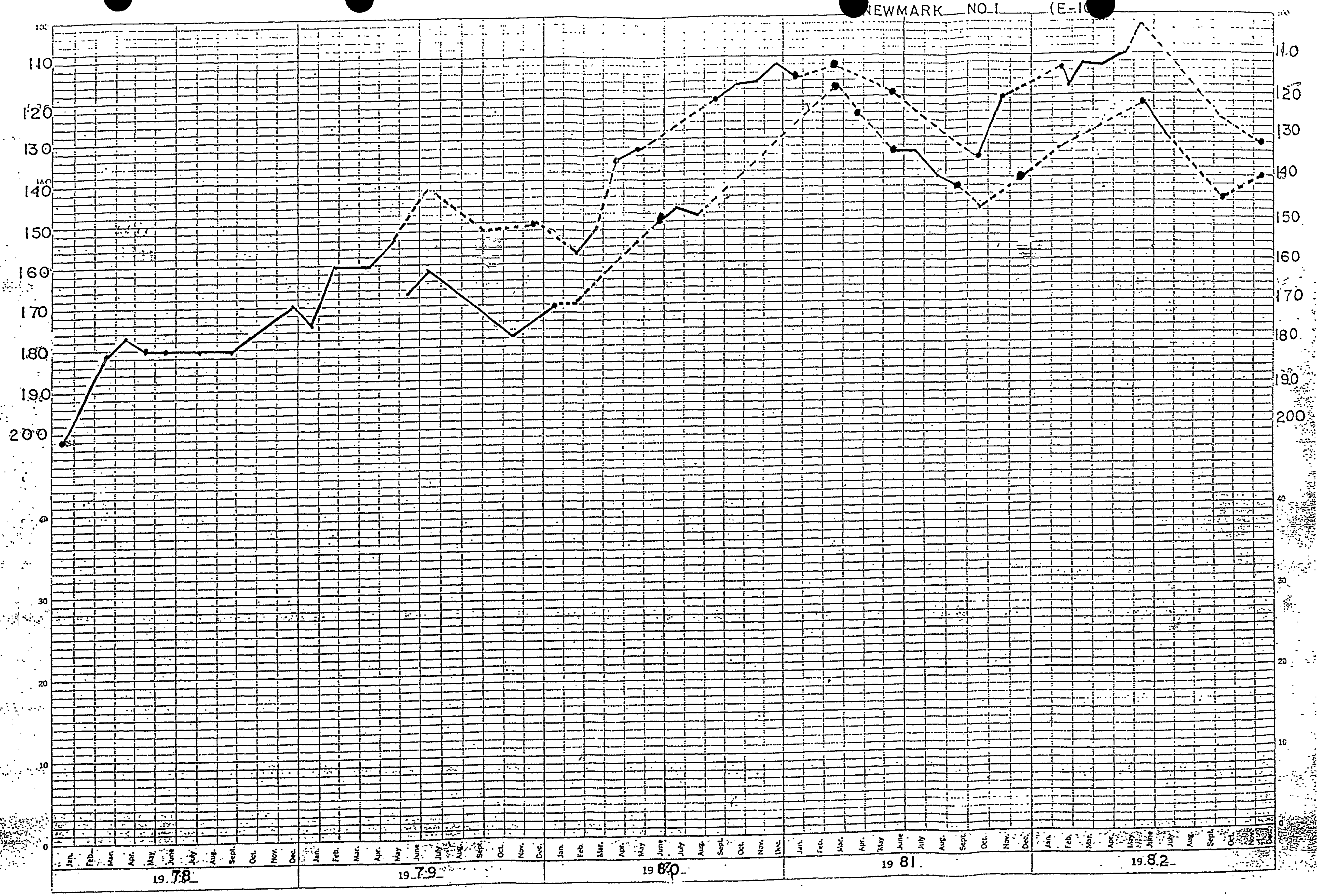

NEWMARK NO.1 (E-1
19 78
19 79
19 80
19 81
19 82
110
120
130
140
150
160
170
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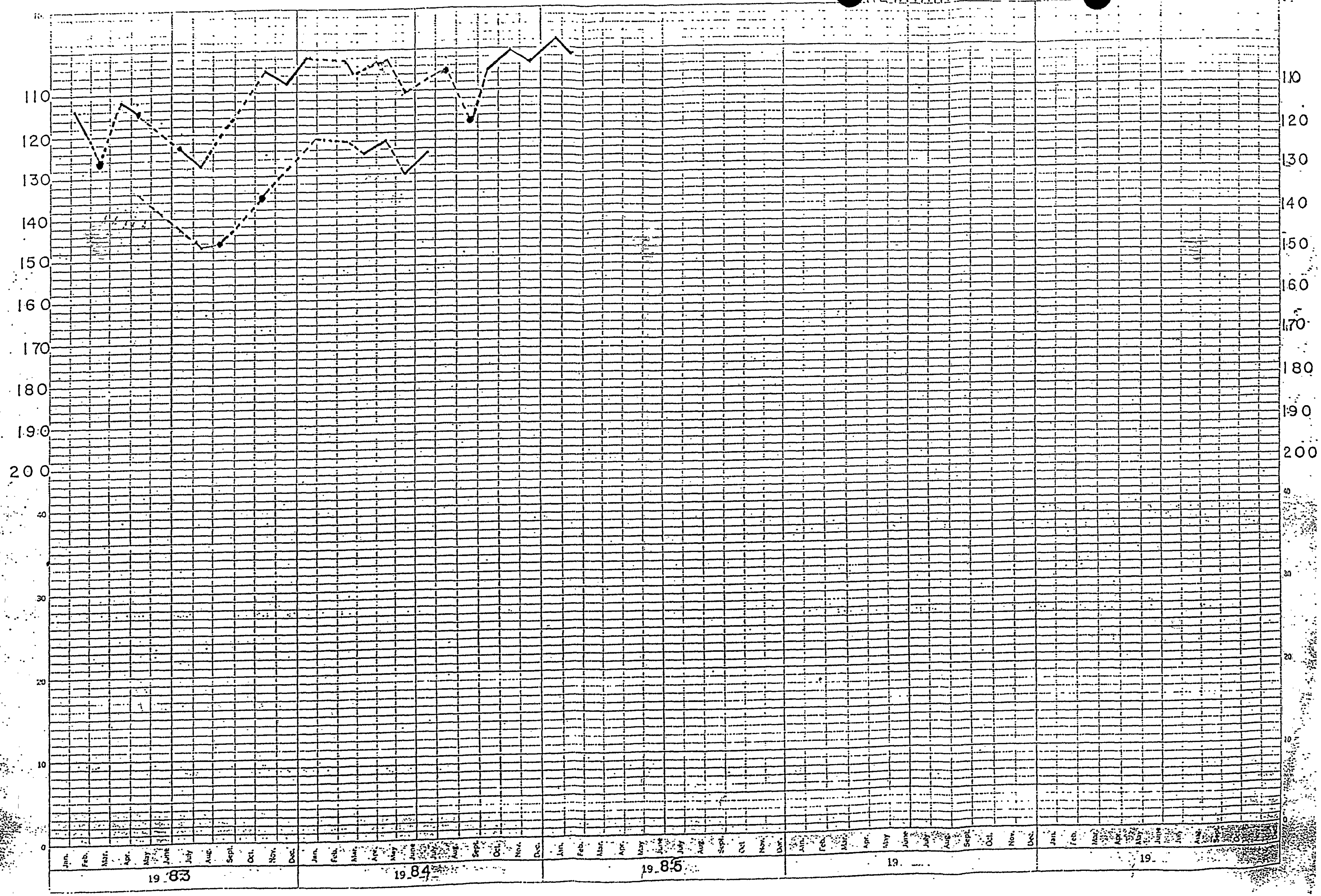
190
200
K+E 5 YEARS BY MONTHS X 100 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
47 3653

NEWMARK NO.1 (E-10



K+E 5 YEARS BY MONTHS X 100 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

47 3653

CITY01355
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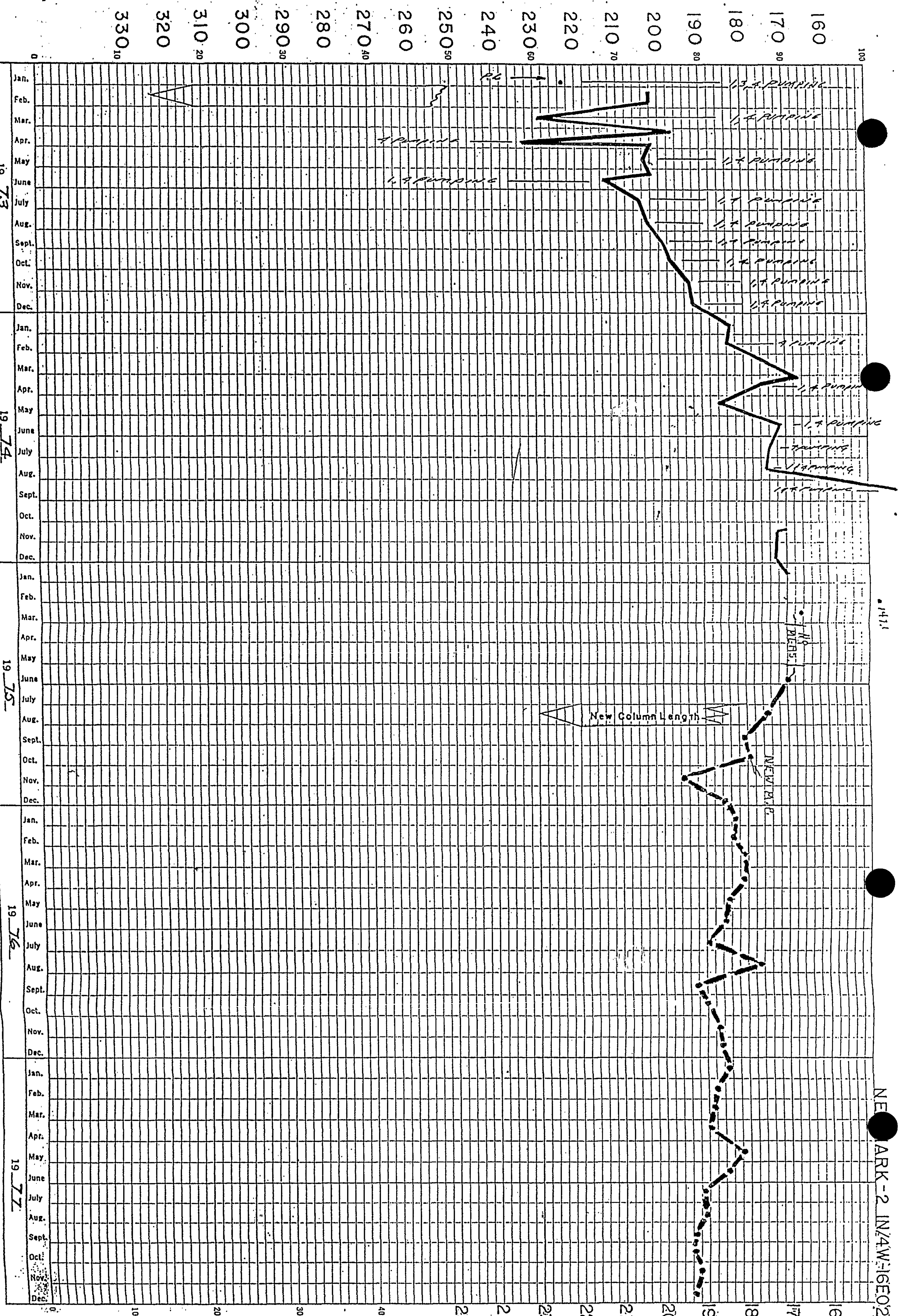
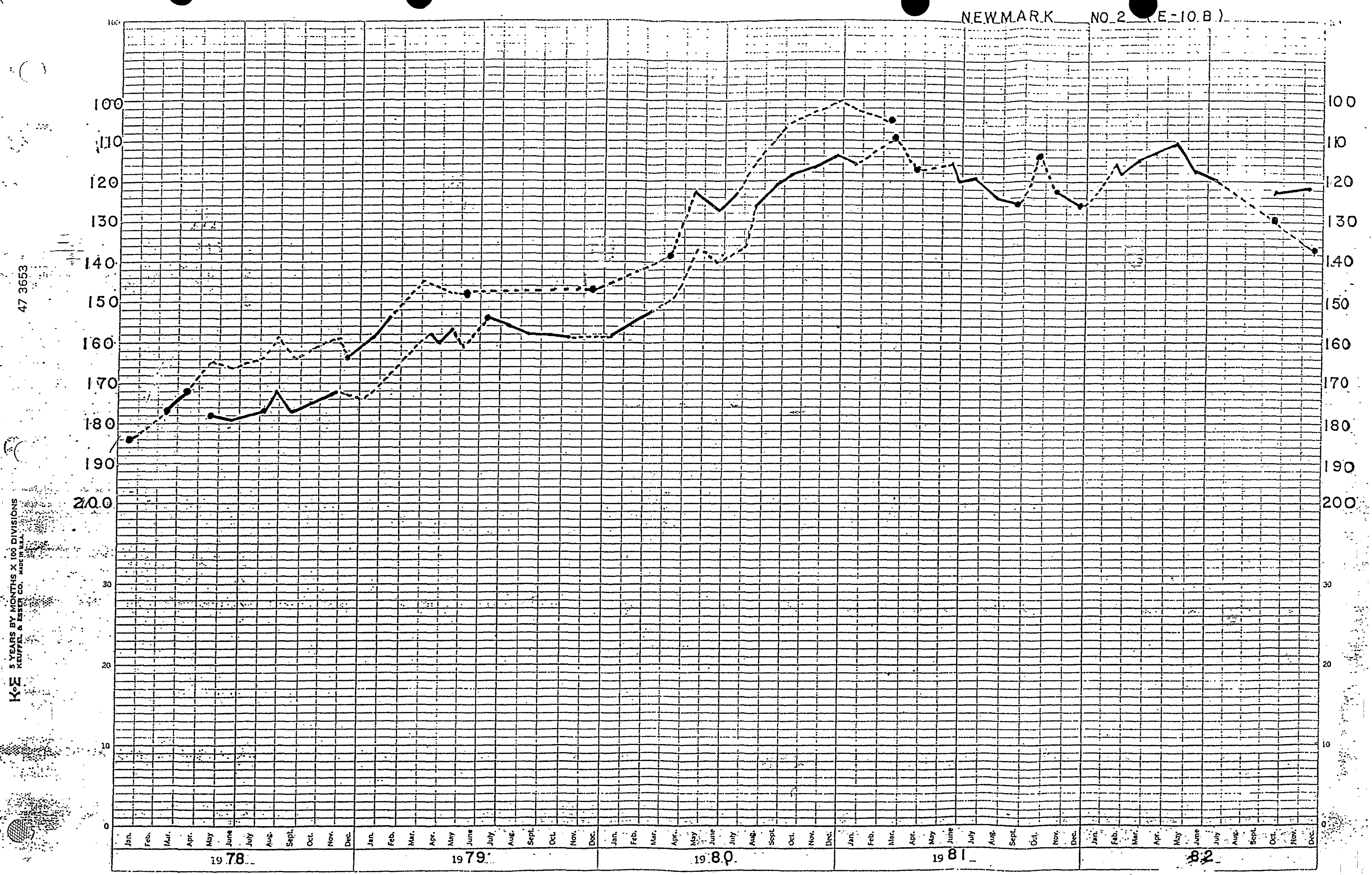
K&E 5 YEARS BY MONTHS X 100 DIVISIONS 47 3653
MADE IN U.S.A.
KEUFFEL & ESSER CO.





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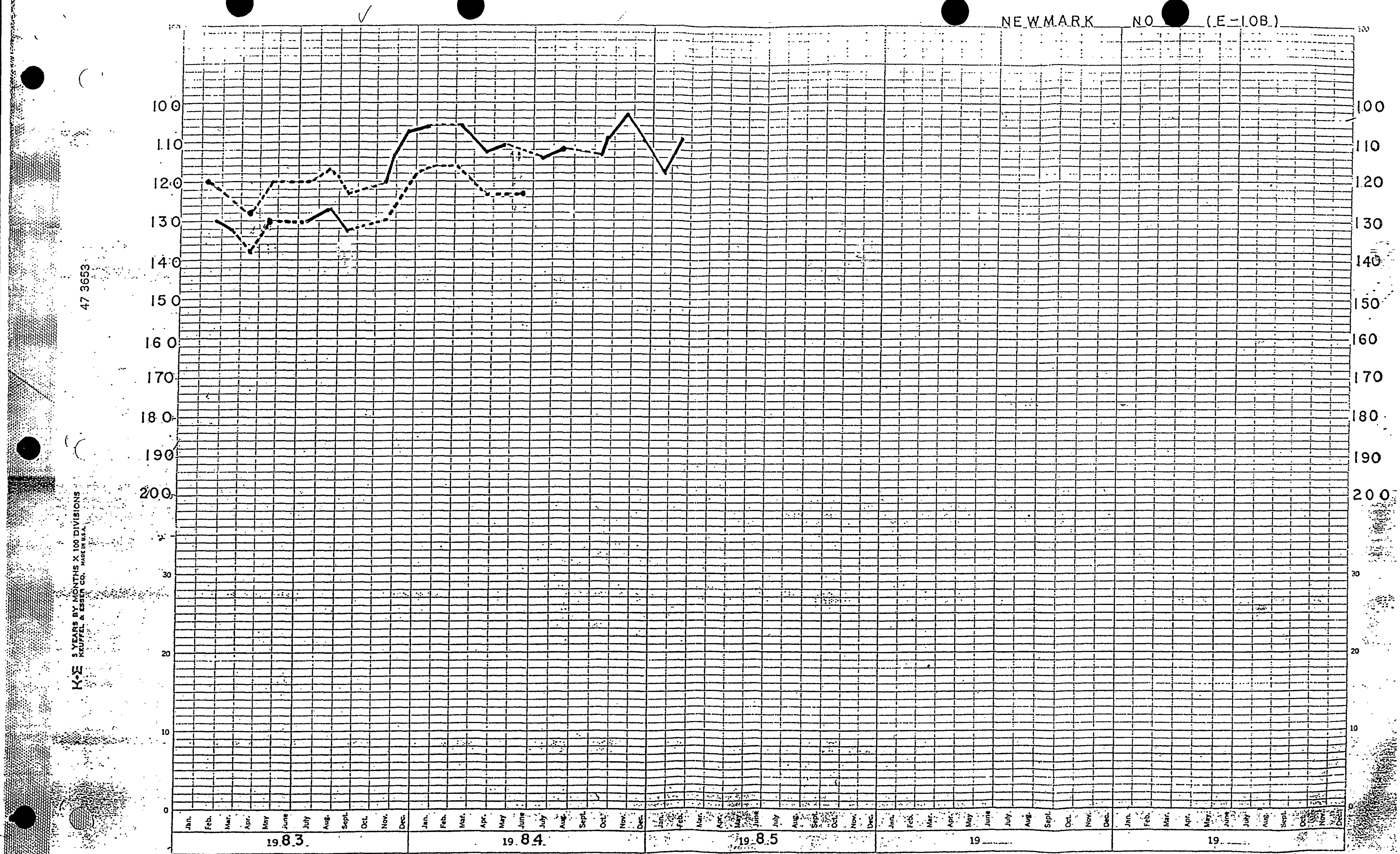

CITY01358
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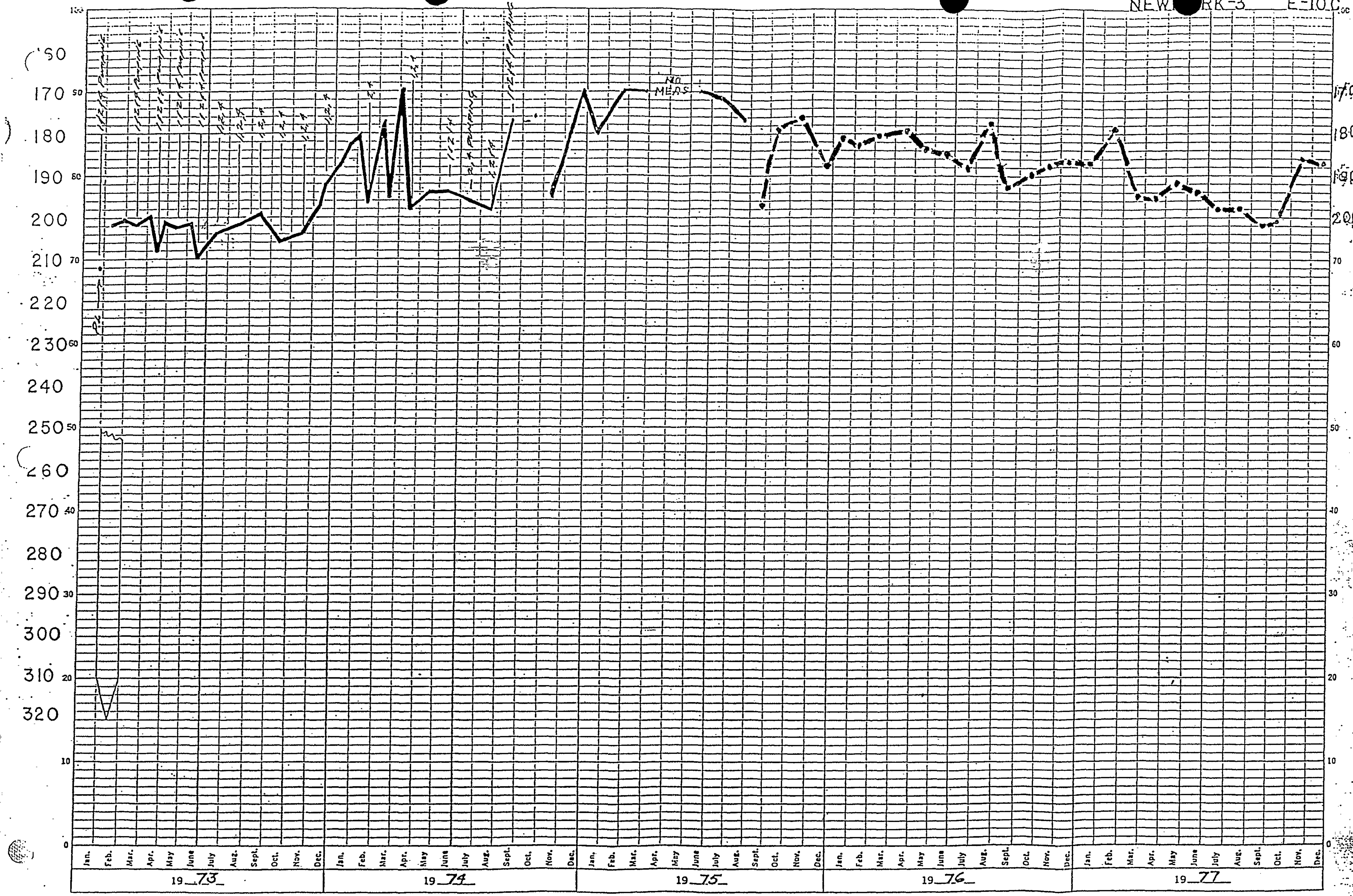
NEW[illegible]RK-3 E-10C



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Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
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19 74
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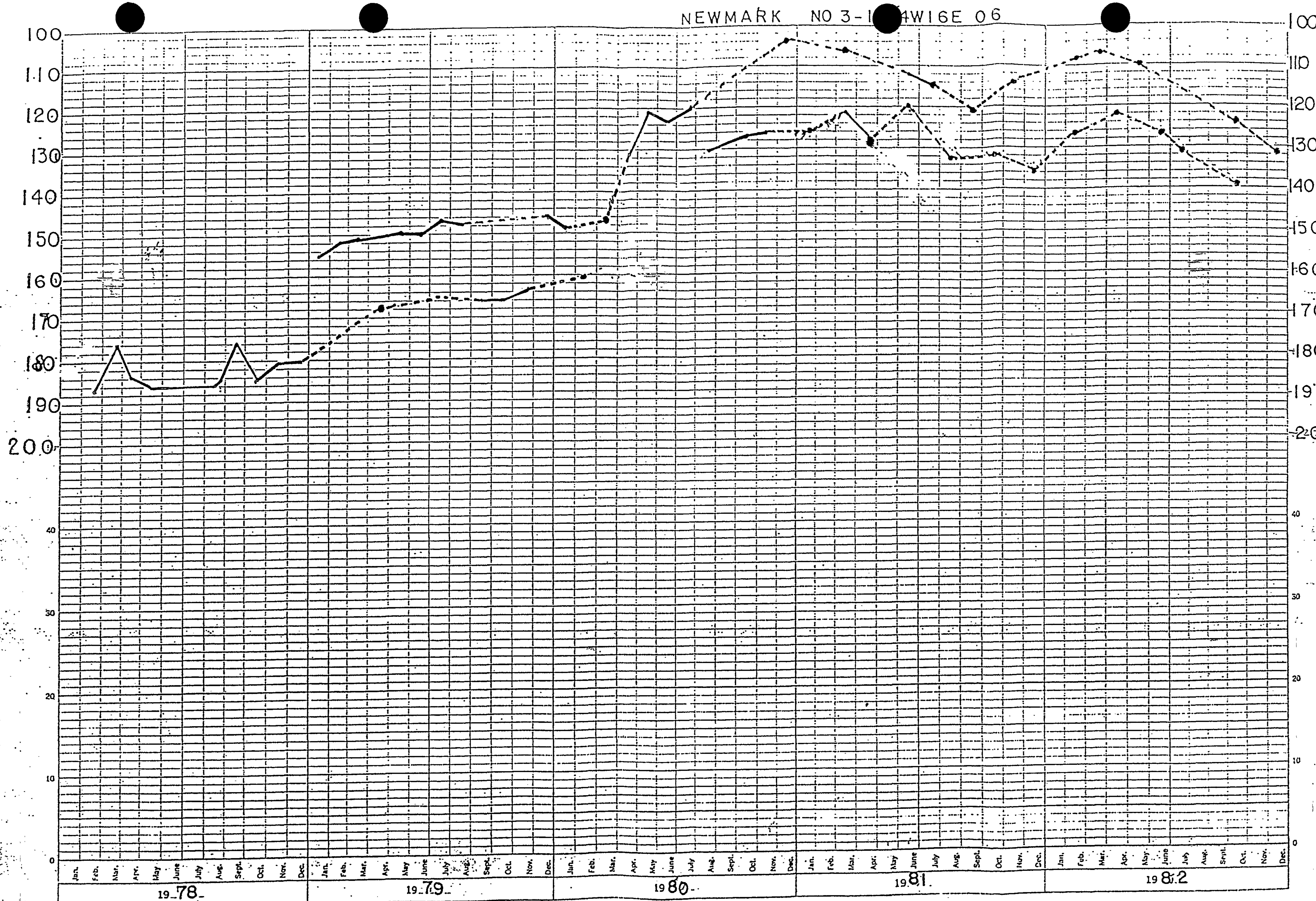

K&E 5 YEARS BY MONTHS X 100 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A.

47 3653

CITY01360
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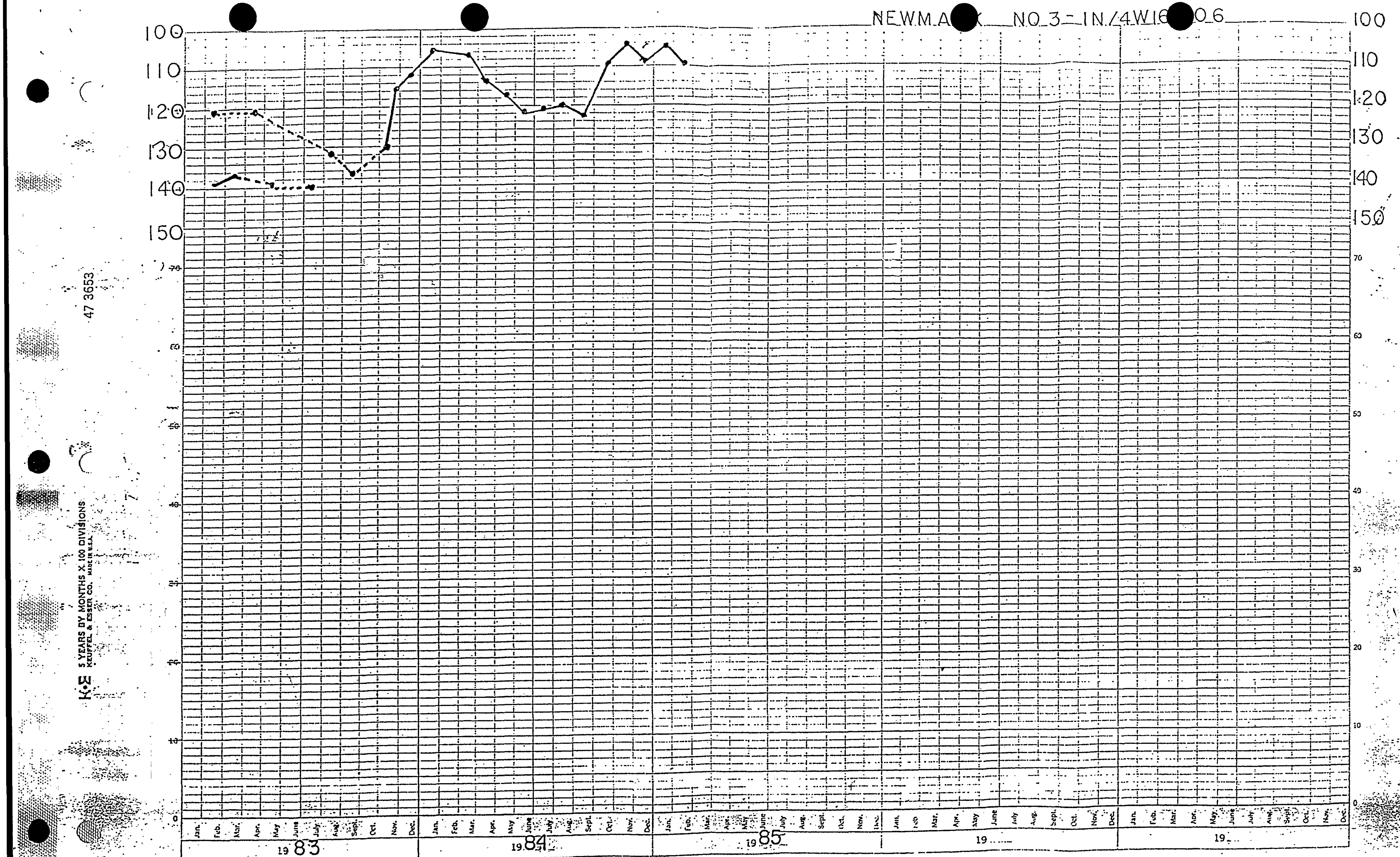

CITY01361
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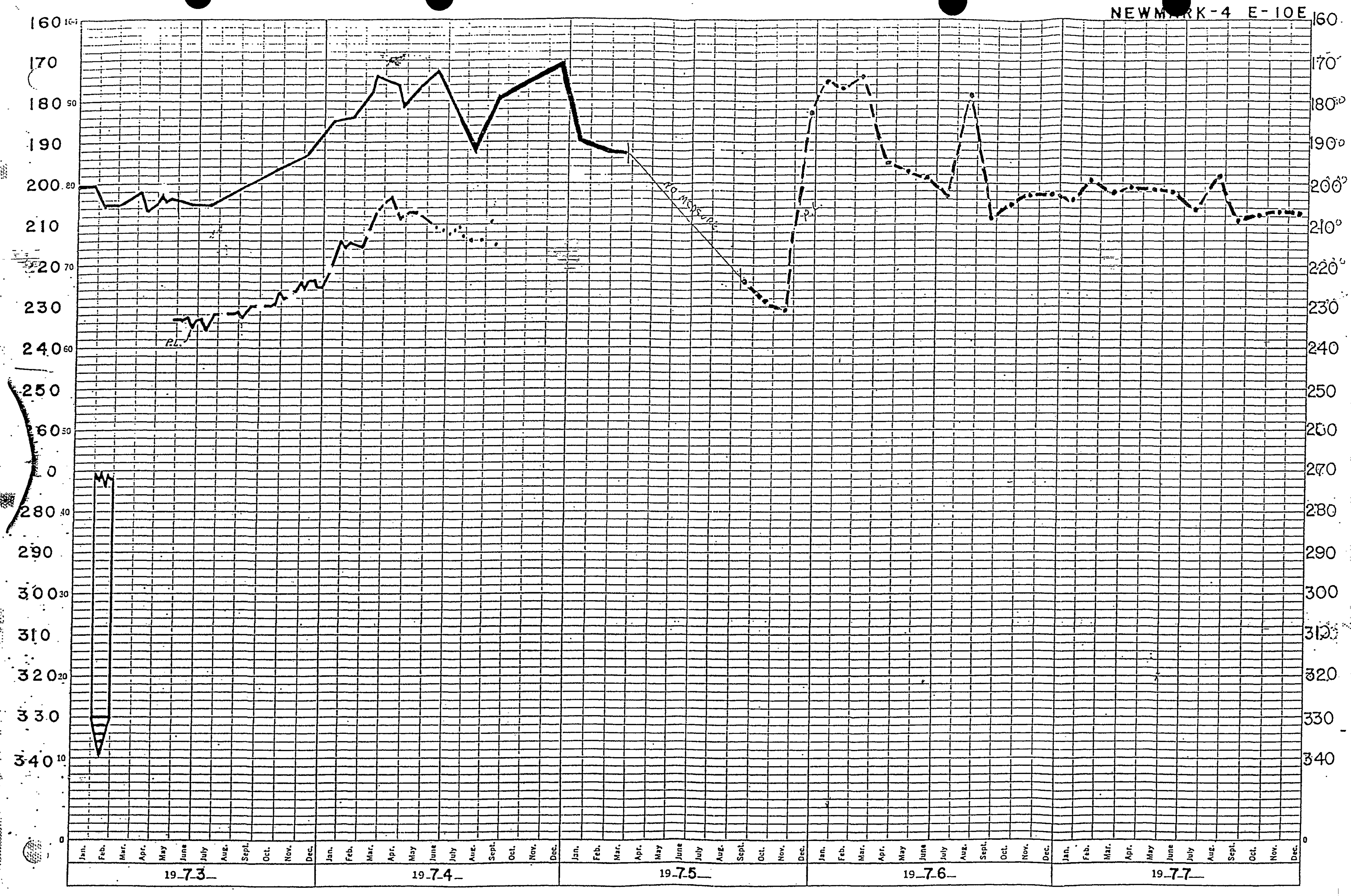
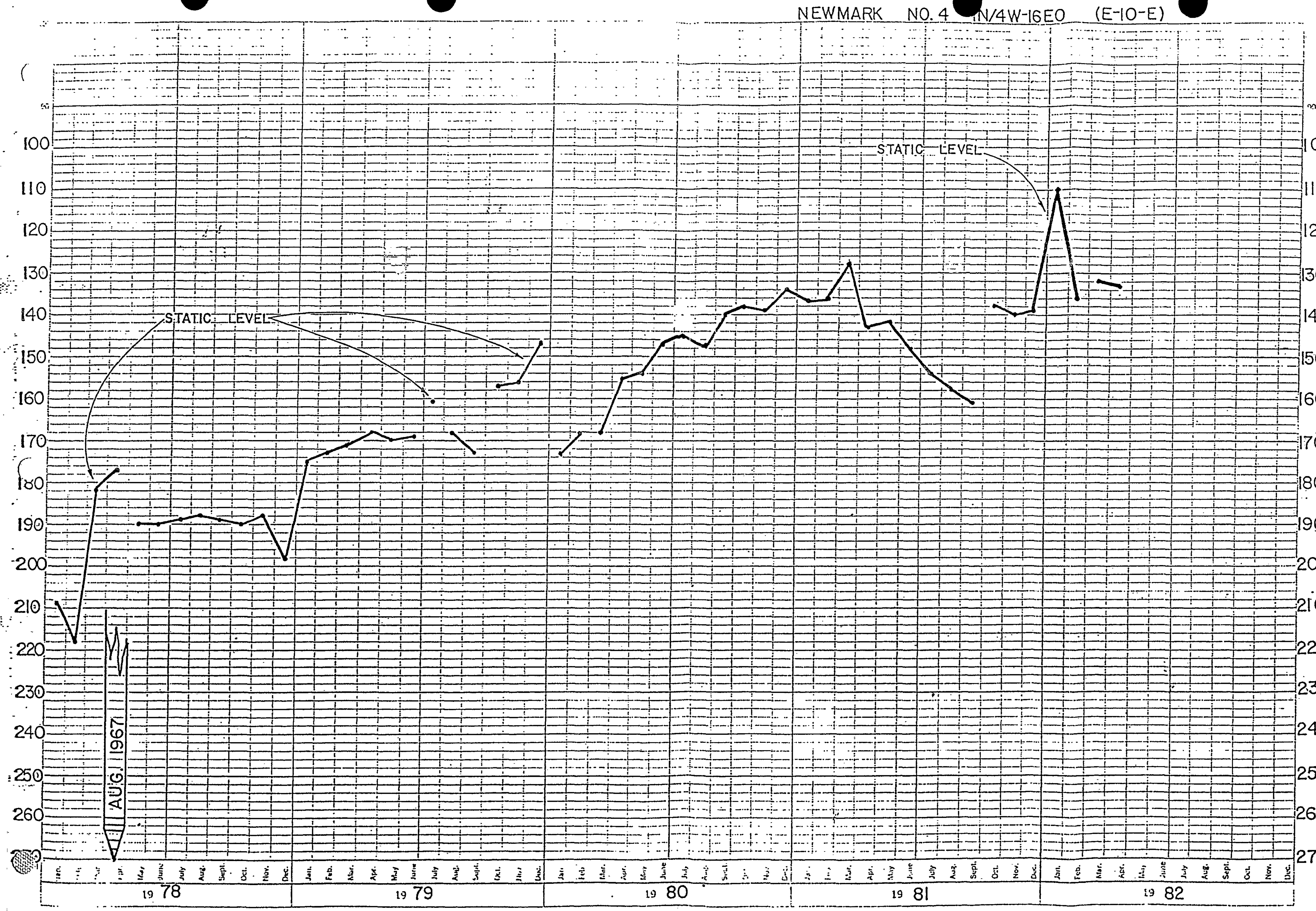

NEWMARK-4 E-10E
160
170
180
190
200
210
220
230
240
250
260
280
290
300
310
320
330
340
NO MEASURE
P.L.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
1973
1974
1975
1976
1977



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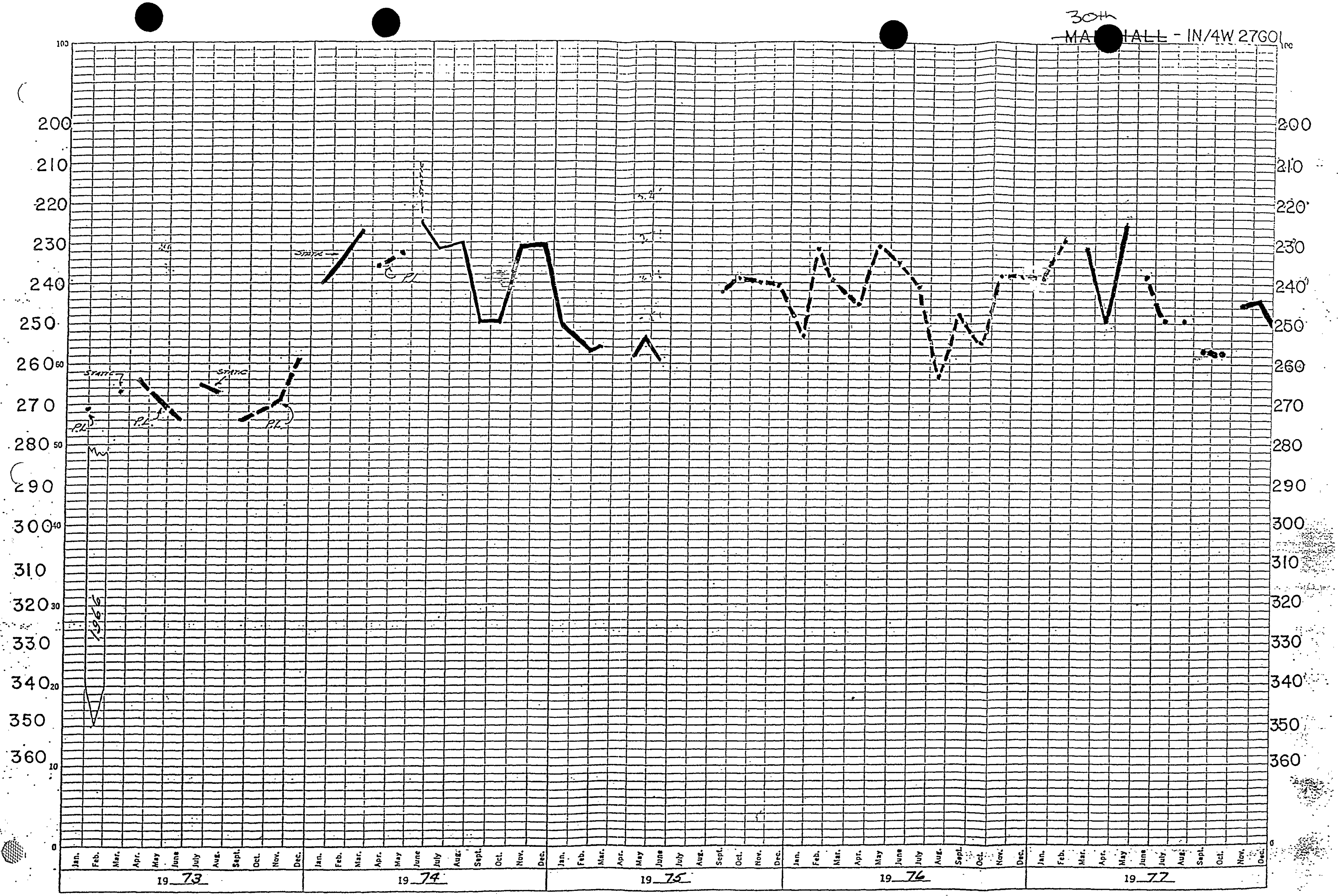

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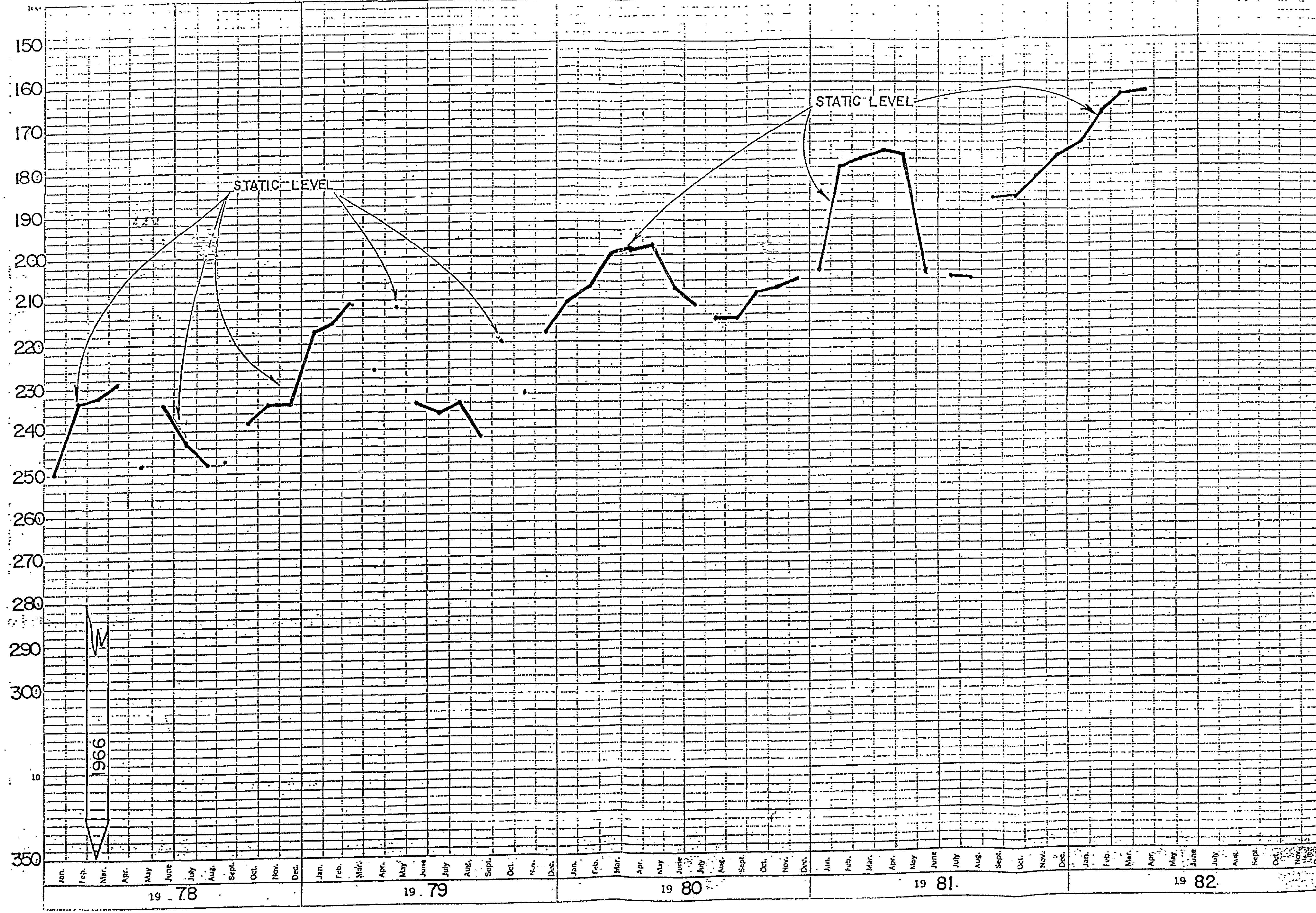
MARSHALL WELL 1N/4W.2 01 (E-25-G)



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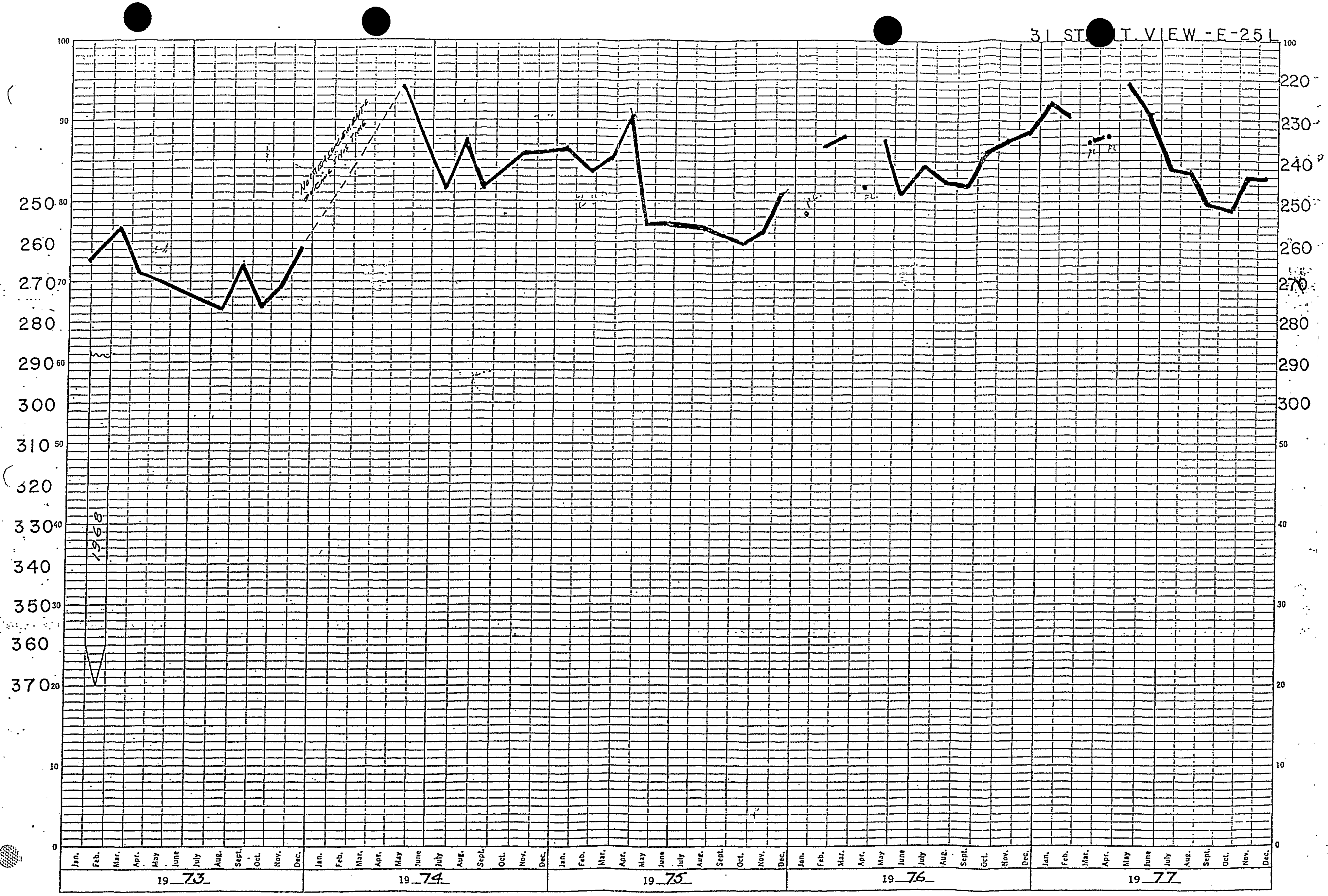

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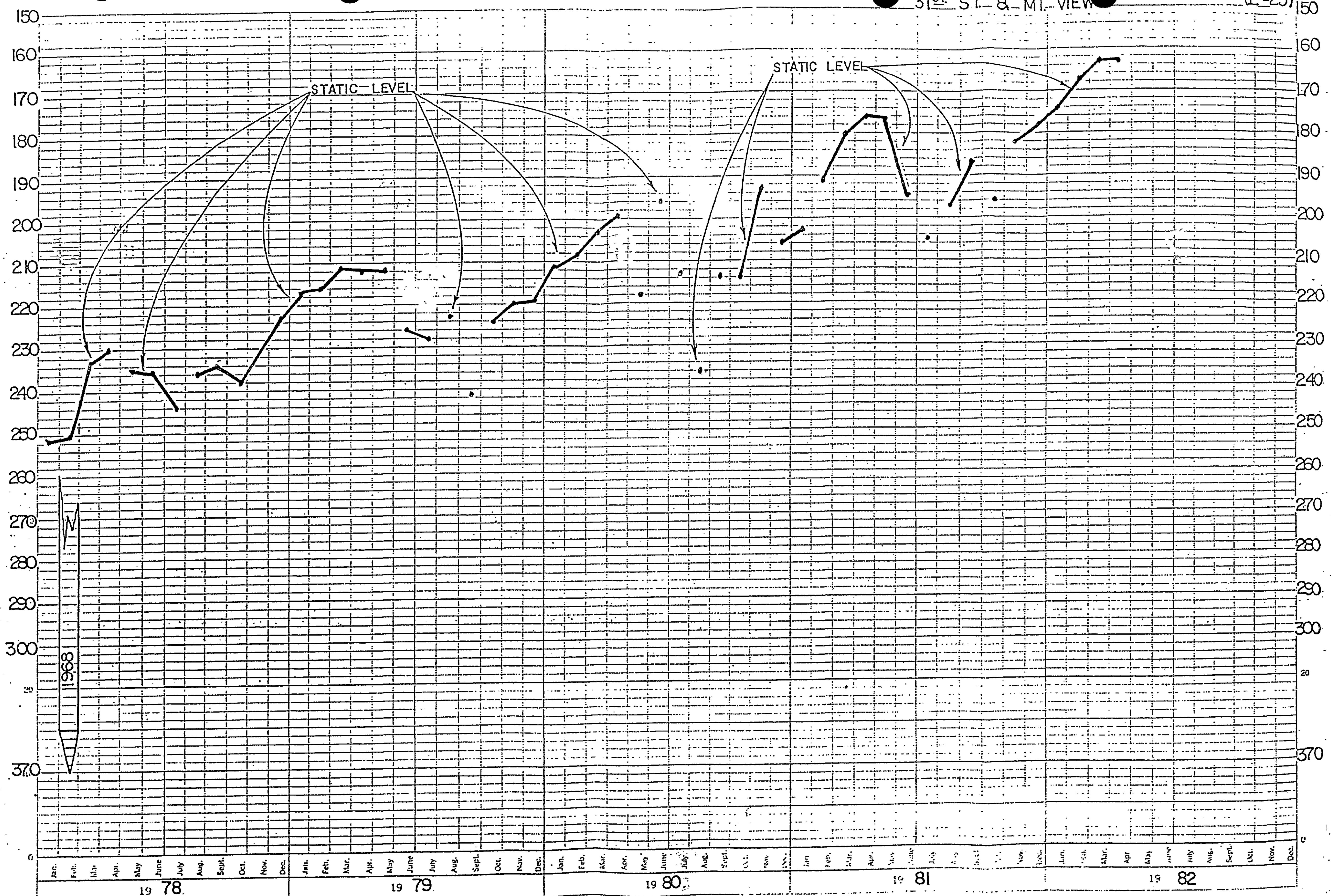
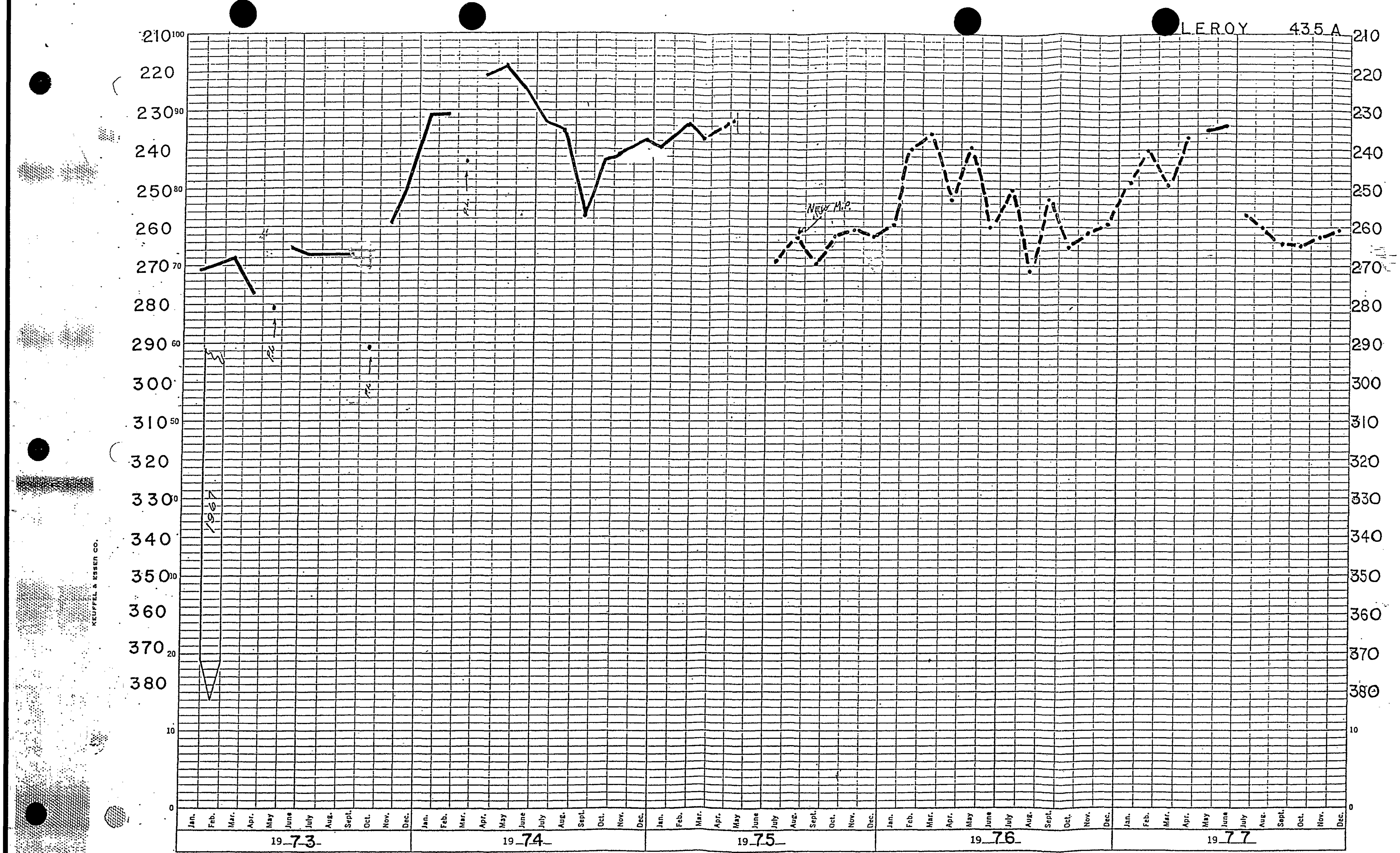
31st ST. & MT. VIEW (E-25)





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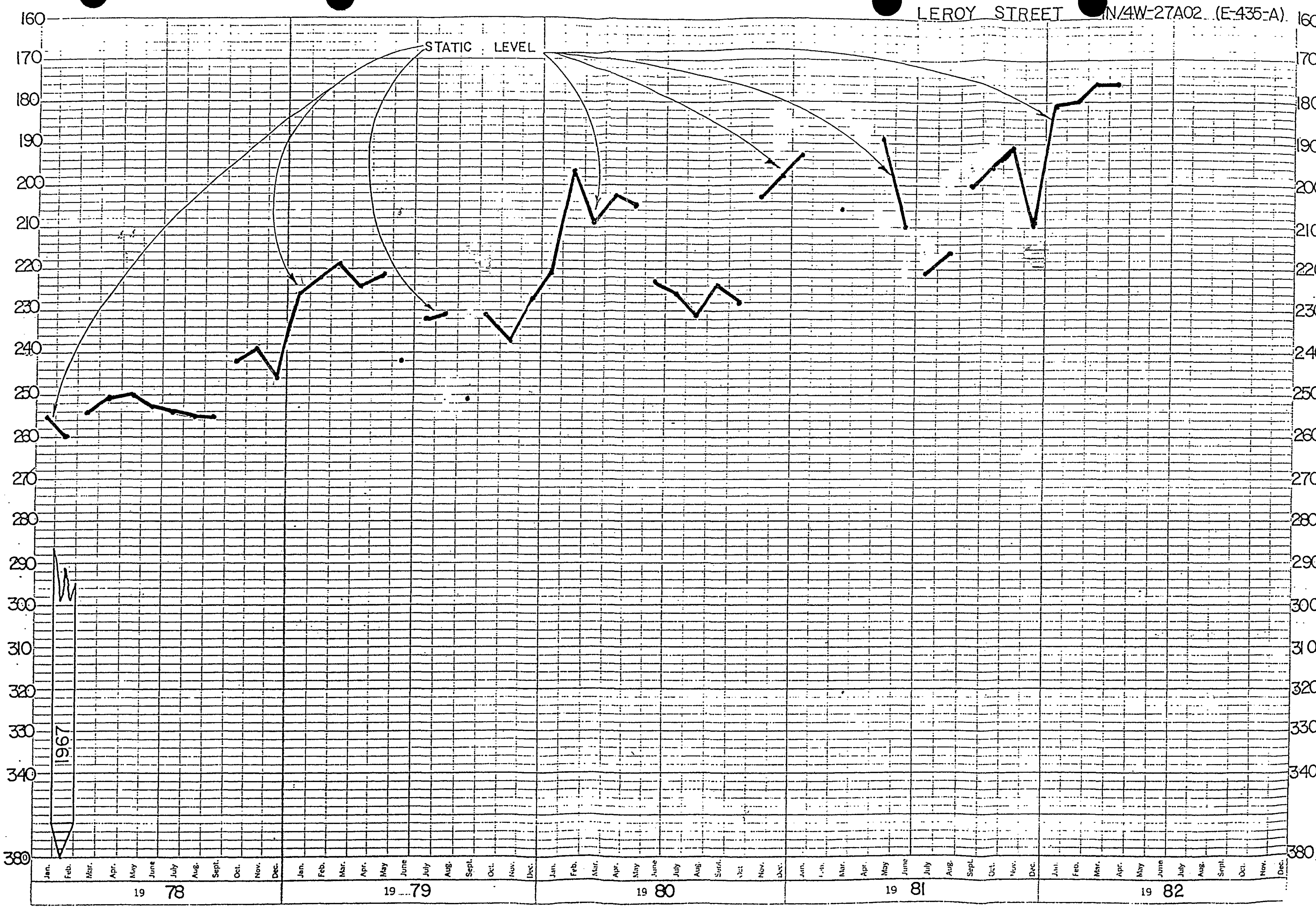

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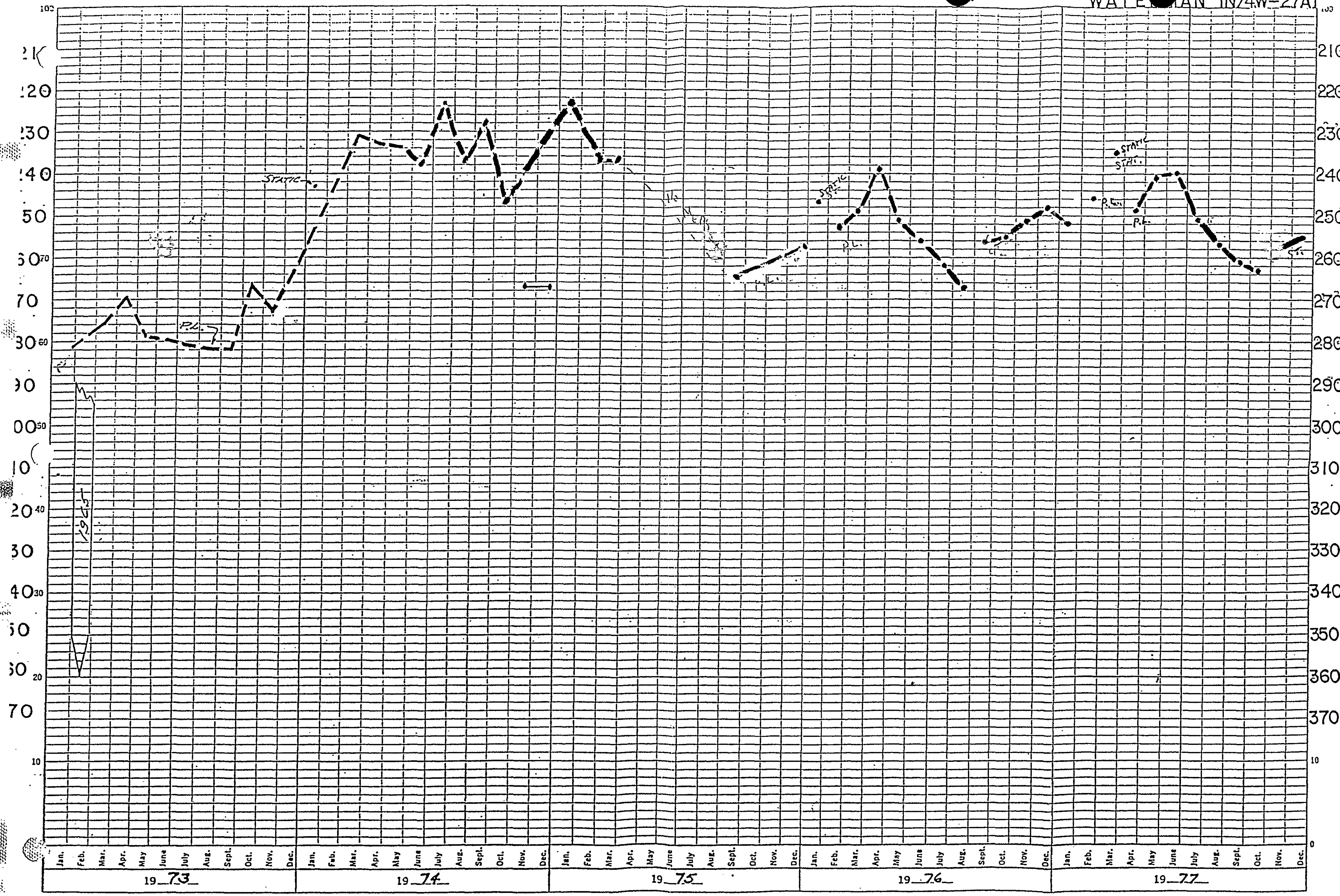
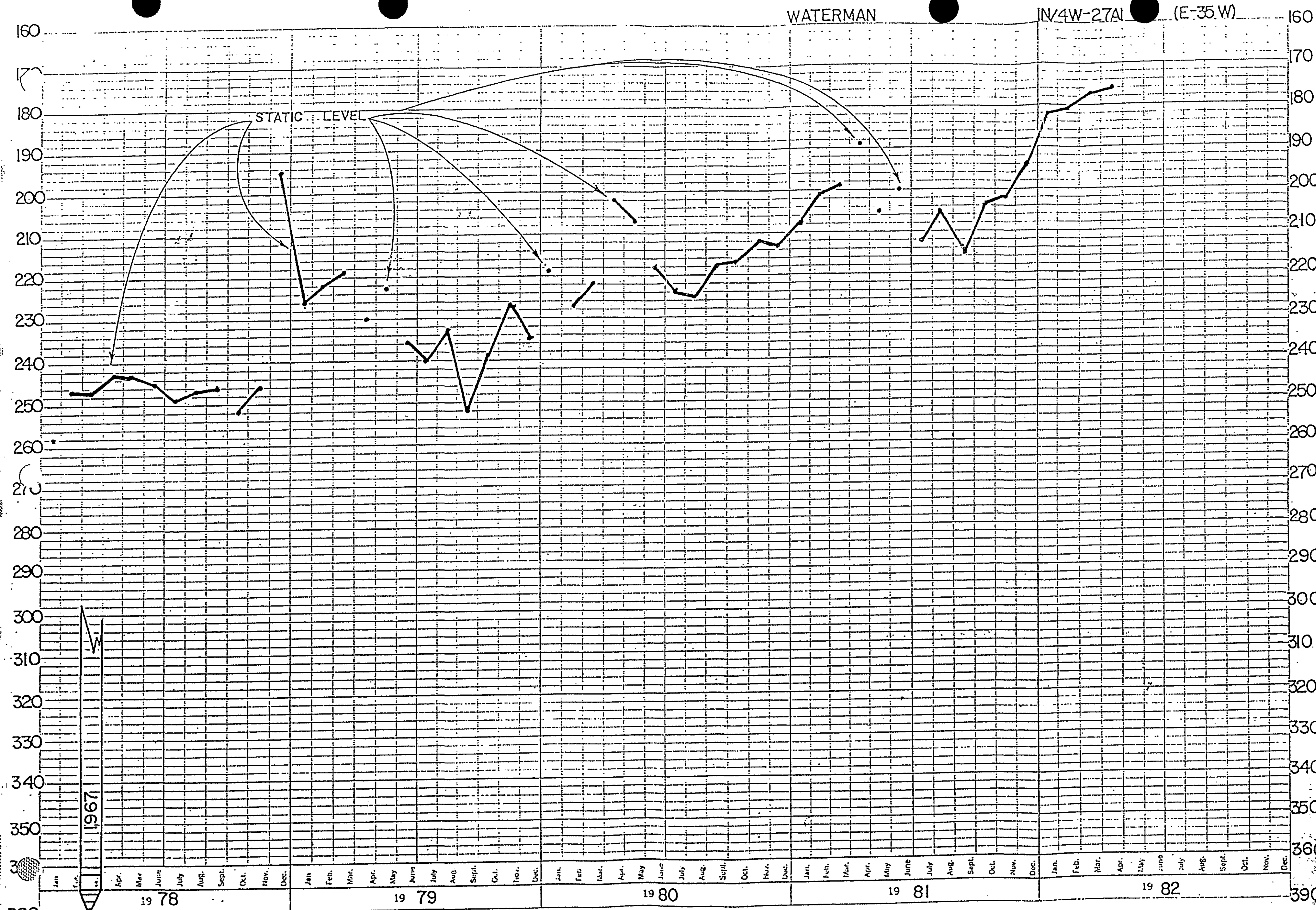
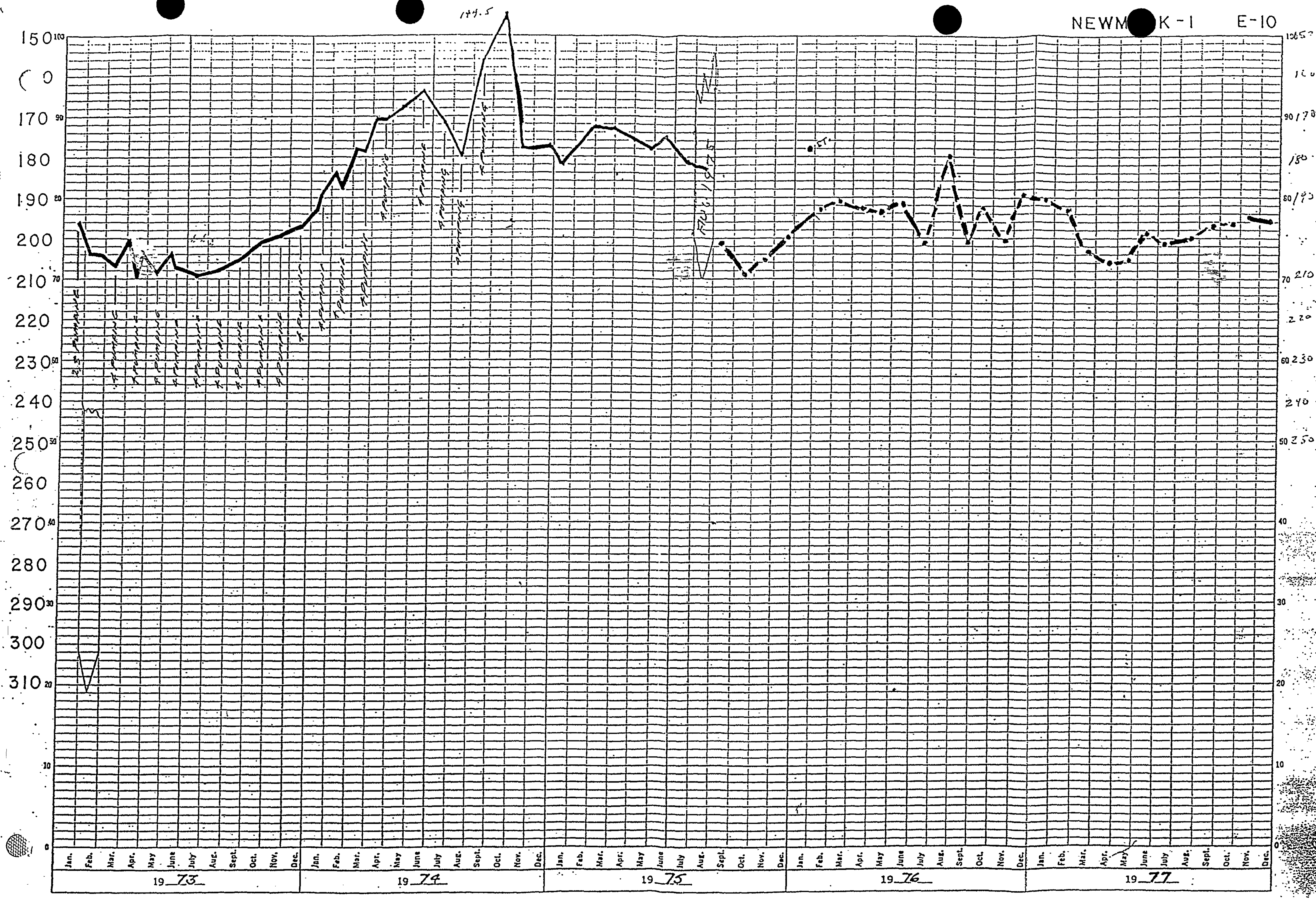
WATE[illegible]AN 1N/4W-27A1




WATERMAN
1N/4W-27A1 (E-35W)
STATIC LEVEL
1967
19 78
19 79
19 80
19 81
19 82

CITY01371

NEWM[illegible]K-1 E-10



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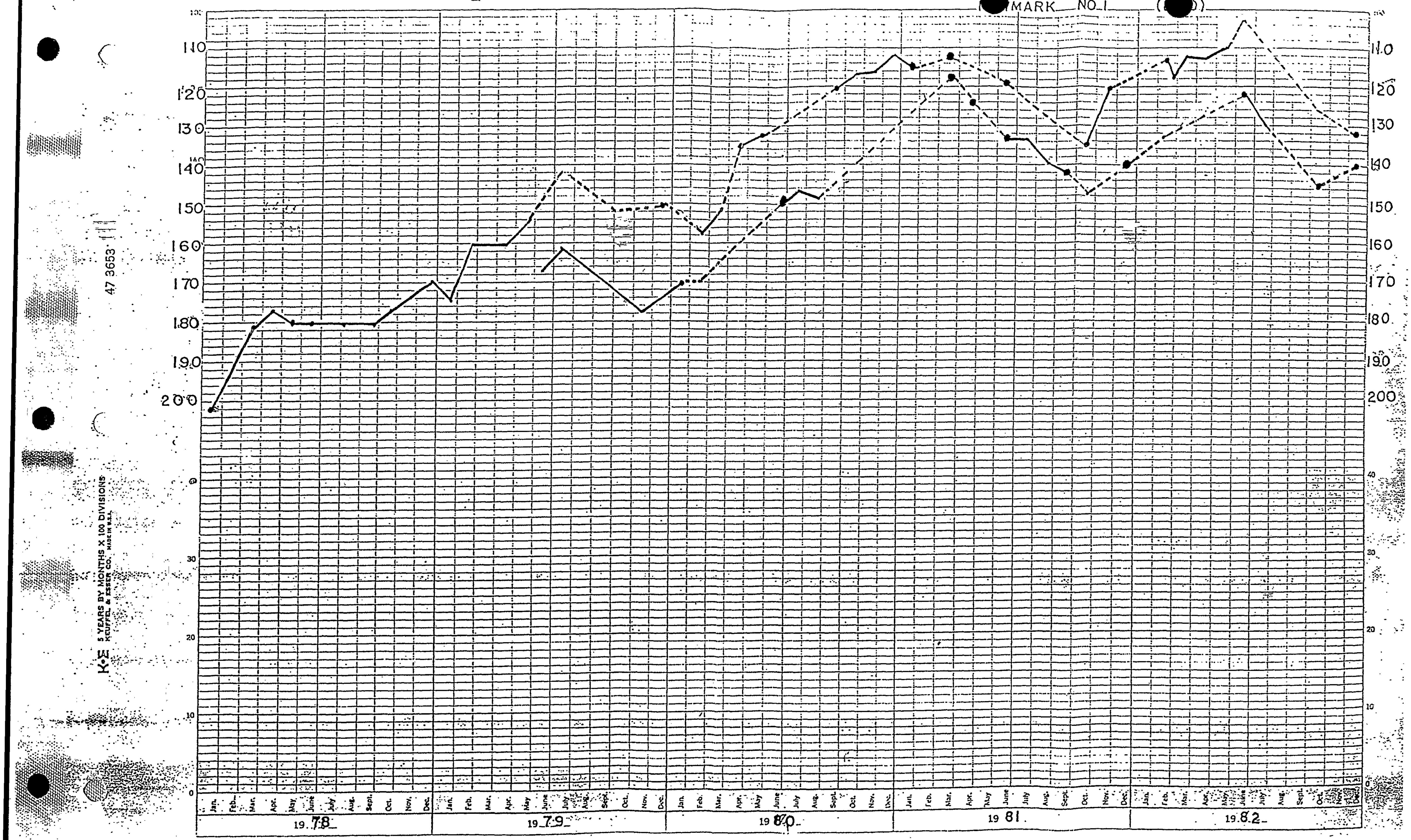

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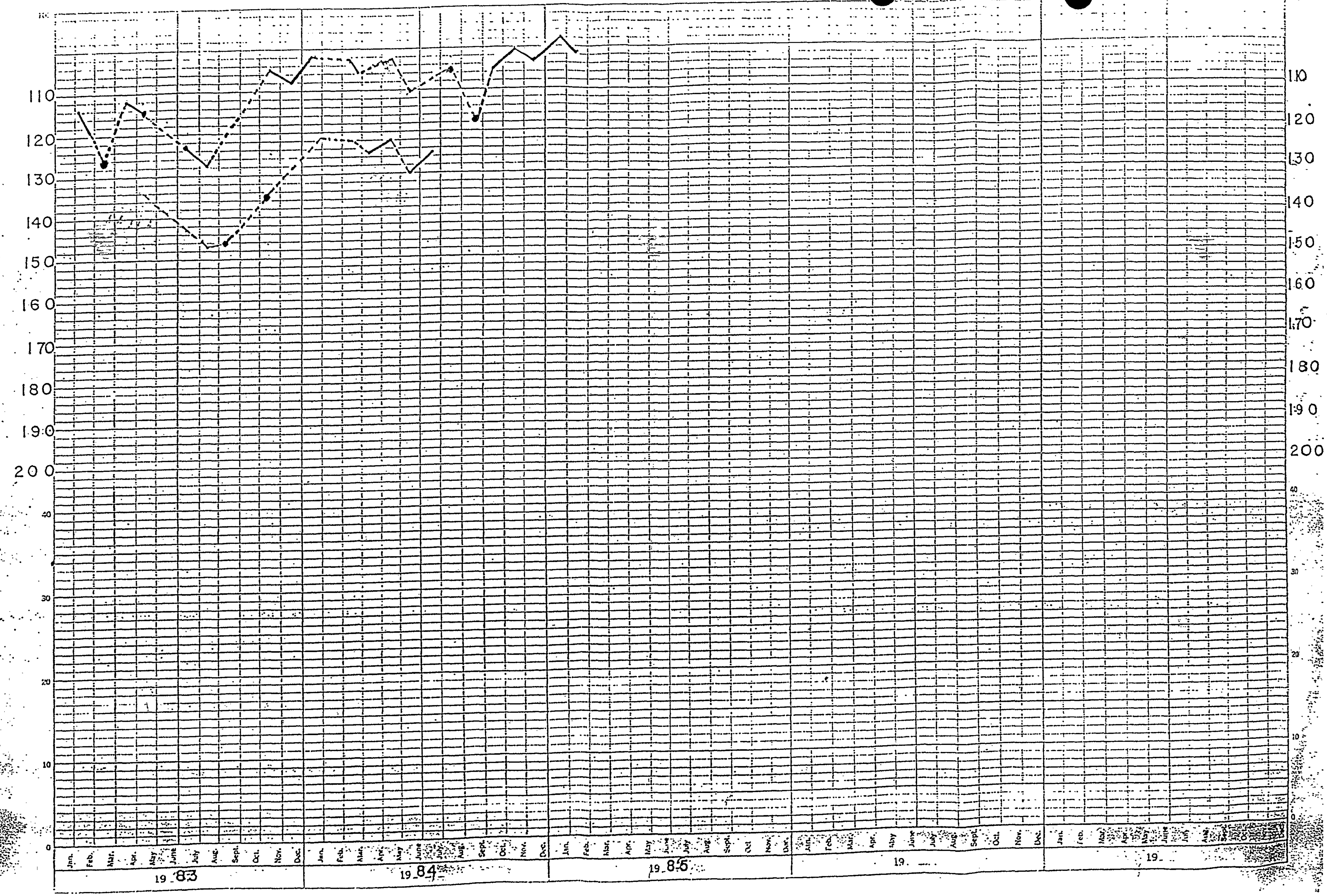
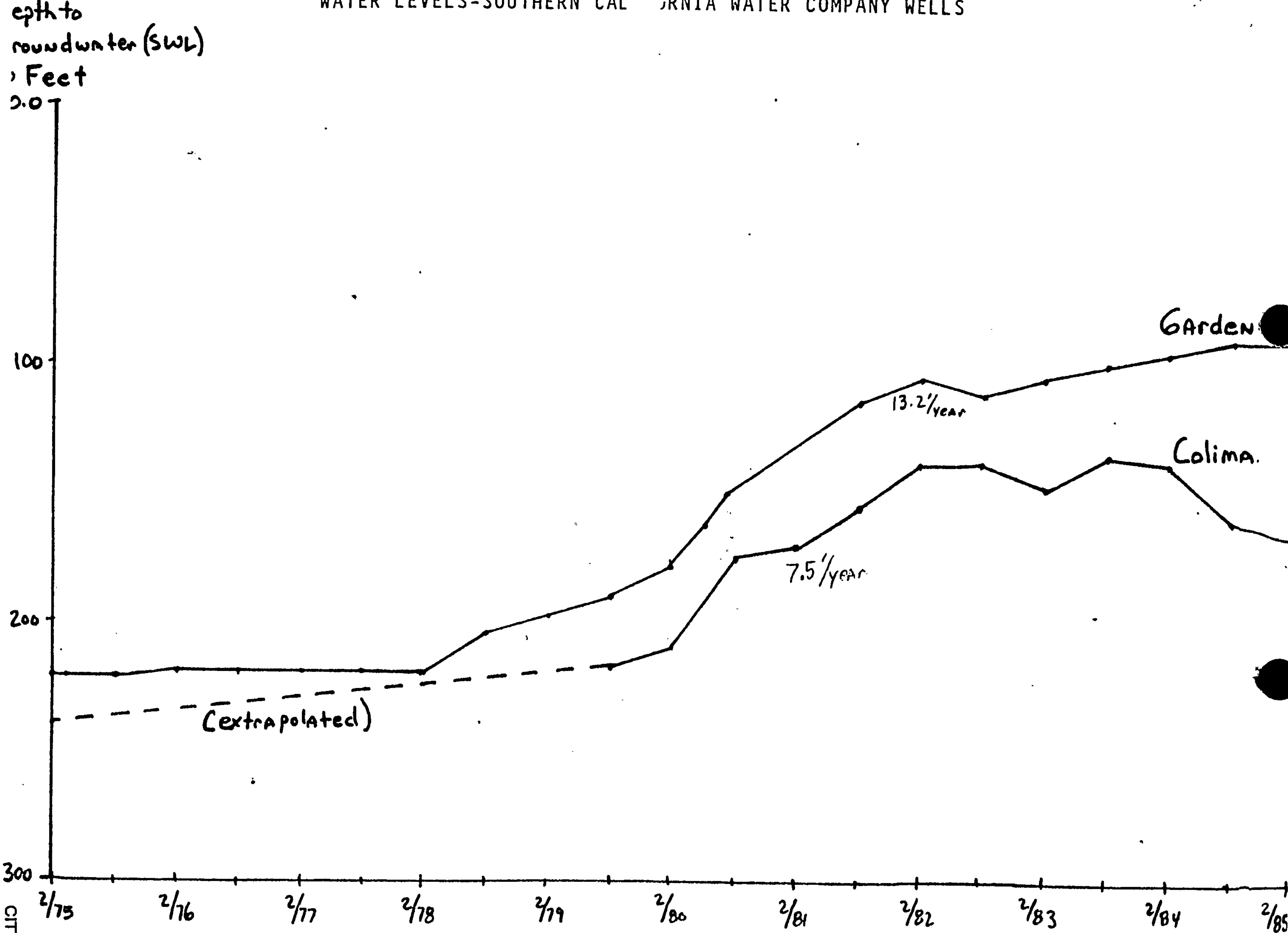
WMARK NO 1 (E)



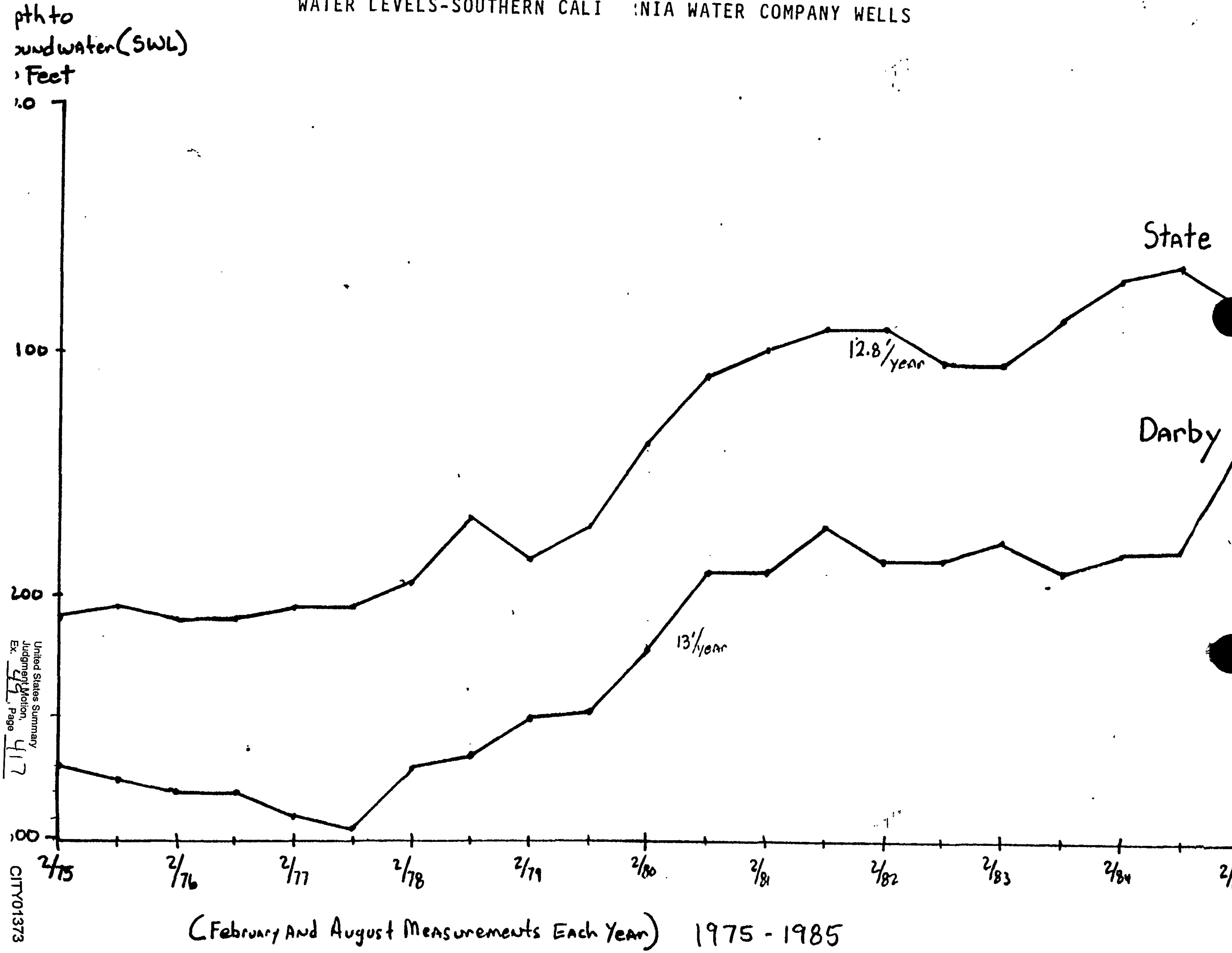
K+E 5 YEARS BY MONTHS X 100 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
47 3653
110
120
130
140
150
160
170
180
190
200
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
19 83
19 84
19 85
19.
19.

WATER LEVELS-SOUTHERN CAL ,RNIA WATER COMPANY WELLS



(February and August Measurements Each Year) 1975-1985

WATER LEVELS-SOUTHERN CALI :NIA WATER COMPANY WELLS



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CITY01373

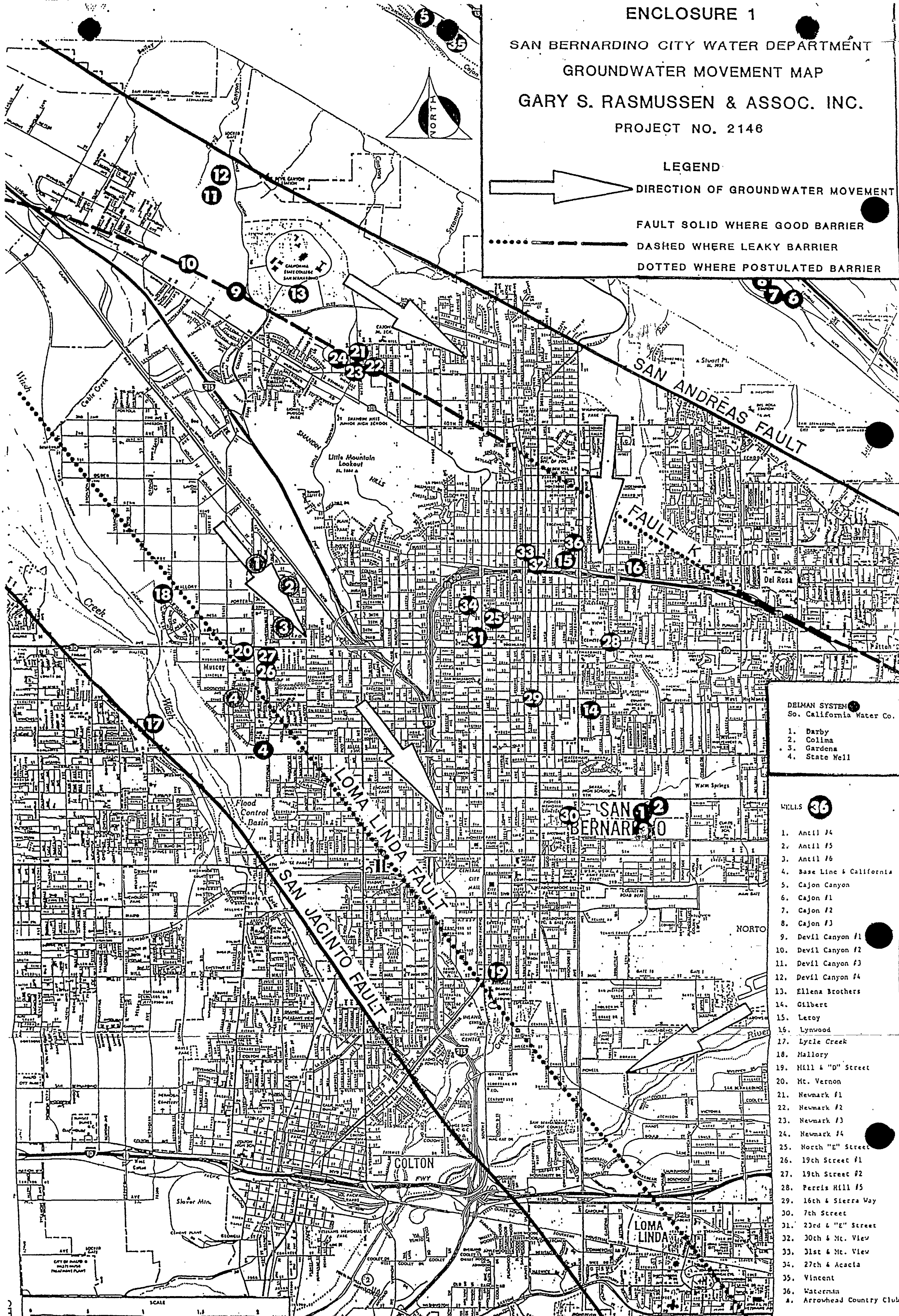

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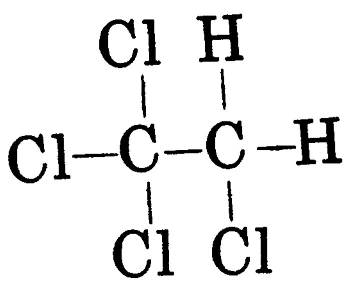
Exhibit 50

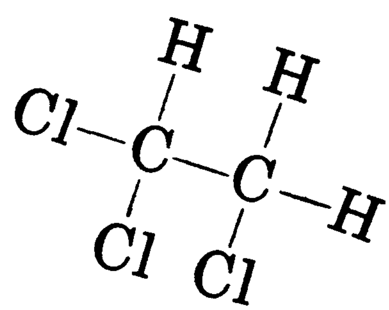
City of
San Bernardino

MUNICIPAL WATER DEPARTMENT

PCE/TCE REMOVAL
1985

Cl_3CCH_2Cl





Cl_2CHCH_2Cl

JOHN CAROLLO ENGINEERS

PHOENIX, AZ · WALNUT CREEK, CA
FOUNTAIN VALLEY, CA · VISALIA, CA
TUCSON, AZ · SAN DIEGO, CA

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CITY01597

JOHN CAROLLO ENGINEERS

PHOENIX, AZ • WALNUT CREEK, CA
FOUNTAIN VALLEY, CA • VISALIA, CA
TUCSON, AZ • SAN DIEGO, CA
ANCHORAGE, AK

May 9, 1985
F02777A0

Mr. Herb Wessel, General Manager
City of San Bernardino
Municipal Water Department
P. O. Box 710
San Bernardino, CA 92401

Attention: Mr. Joe Stejskal

Re: Final Report - PCE/TCE Removal

Gentlemen:

We are pleased to submit herewith our report on the above-referenced subject. Our findings indicate that:

a) TCE and PCE contamination can be substantially reduced by the proposed air-stripping methodology.

b) An effective tower height of at least 17-feet should be used for final design. This tentative height may be increased to in excess of 20 feet during final design to account for increasing contamination trends, safety factor, etc.

c) While design proceeds, a final proof of concept run should be completed with the pilot plant packing height increased to 17-feet.

d) The City should blend the treated water from the stripping tower with other source water to insure that action levels with PCE/TCE are maintained.

e) PCE (Tetrachloroethylene) has proven itself to be more difficult to remove than TCE (Trichloroethylene). This is somewhat of a surprise since Henry's Constant (H) for PCE is considered higher than for TCE.

f) PCE will be the controlling effluent parameter in the selection of tower height; etc.

g) The City's operational methodology will determine how many towers should be designed-constructed at this time.

During the preparation of this report, the City, through separate contract by others, prepared a specific geology review of the groundwater basin situated to the northwest. This recent report further suggests and/or concludes that:

CITY01598

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a) The Barrier K does influence groundwater movement in the vicinity of the contaminated plume.

b) The level of contamination and associated mixing can be expected to increase as the plume moves southeasterly from the Newmark Reservoir site.

c) The contaminated plume should be intercepted and treated prior to a southerly movement of the plume east of the Shandin Hills area.

To help accomplish the above, it is imperative that PCE/TCE treatment be accomplished at the Newmark Reservoir site at the earliest date possible. For that level of contamination passing Barrier K and proceeding in a southerly direction, PCE/TCE treatment should be accomplished in the vicinity of the Waterman Reservoir site. Also, based on test work that may be accomplished by others, it may prove prudent to establish a treatment site prior to the easterly edge of the Shandin Hills area.

We are basically complete with our preliminary investigation, and can immediately proceed with final design of the required towers. As always, it has been a pleasure working with you and your staff on this project. Particular thanks is offered to all those persons who help design-construct-operate the pilot plant facility. The pilot plant program has proven itself very worthwhile, and has provided sound design information that, in our judgment, will save capital and operational dollars.

Special thanks is offered to the Department of Health Services for their assistance, cooperation, and participation in the VOC test program, and to the Santa Ana Regional Water Quality Control Board for their assistance in defining the potential source-areas of contamination, funding resources, and overall treatment strategies.

Very truly yours,

JOHN CAROLLO ENGINEERS

Gail P. Lynch

Charles A. Griffin, Jr.

CAG:cd
Enclosure

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CITY OF SAN BERNARDINO
MUNICIPAL WATER DEPARTMENT

PCE/TCE REMOVAL
1985

MAY 1985

JOHN CAROLLO ENGINEERS

PHOENIX, AZ • WALNUT CREEK, CA
FOUNTAIN VALLEY, CA • VISALIA, CA
TUCSON, AZ

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CITY01600

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SECTION 1

BACKGROUND

GENERAL

The City of San Bernardino is experiencing contamination of several wells to the extent that it has become necessary to shut down the wells. In October of 1984, the City officially notified the State of California that the following wells and associated capacities would be removed from service until appropriate treatment could be implemented:

Well	Approx. Capacity (gallons per minute)
• Newmark No. 1	1,727
• Newmark No. 2	1,607
• Newmark No. 3	1,761
• Newmark No. 4	2,321
• 30th and Mt. View	1,626
• 31st and Mt. View	2,750
• LeRoy Street	2,970

In late November 1984, John Carollo Engineers was retained to conduct an evaluation of possible treatment options and to suggest a protocol for performing pilot-scale studies. A literature search indicated that air-stripping by countercurrent packed towers would be the most cost-effective treatment option to pursue. The literature also stressed the importance of adequate pilot scale testing.

In December 1984, the City's staff proceeded to construct a pilot test unit. By relative standards, the pilot unit is large in that the tower originally contained 10 feet of media in a 3 foot diameter tower. The tower height was subsequently extended to 20-feet for additional test work. It was determined that the information received would be more valid than the "typical" small pilot plants. Complete details of the unit are on file with the City.

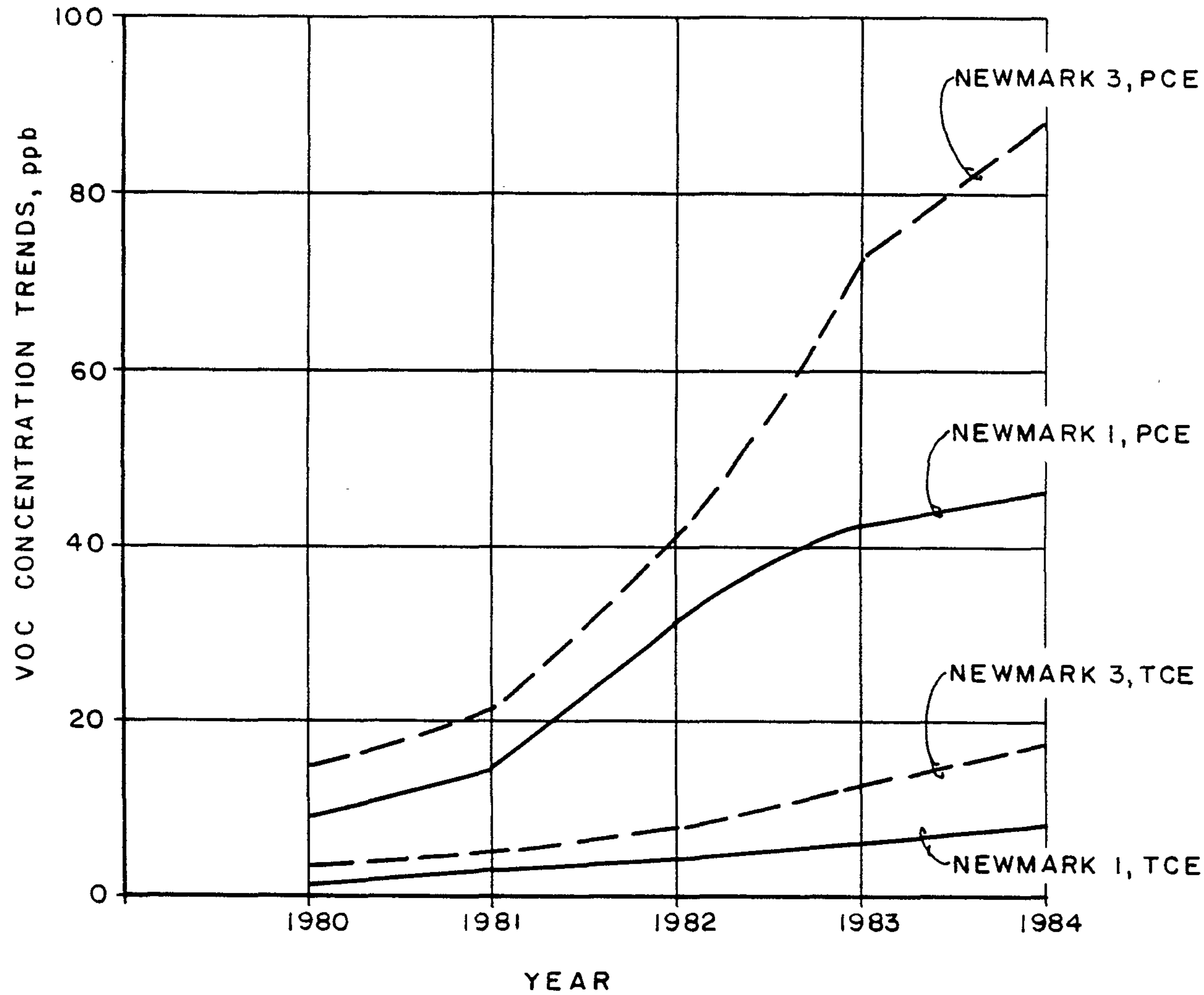
In January 1985, the first test run was conducted at Newmark No. 3. A second test was conducted at Newmark No. 1 in February 1985. A complete discussion of the tests is included later.

VOC CONCENTRATION TRENDS

The pilot scale testing was concentrated on Newmark Wells No. 1 and 3 because they represent, at present, the worst contamination by TCE and PCE. An evaluation of past records indicates that the contamination is progressively worsening with time. Figure 1-1 represents a depiction of the concentration levels. It can readily be seen that PCE contamination levels far exceed TCE levels. Also indicated is the fact that Newmark No. 3 has significantly higher contamination levels than Newmark No. 1.

The most important parameter to be considered in the design of an air stripping concept is the magnitude of the influent concentration that must be removed. At this time it is not known what future concentration can be expected. It is apparent from existing data and the pilot test results that the expected PCE concentration will be the controlling design contaminant. Figure 1-2 is a graphic representation of the required town packing depth that can be expected for various future influent concentrations and effluent residuals of PCE. At existing levels, a 17-foot depth would reduce the effluent level to approximately 2 ppb, or one-half the present State criterion. Based on the trends indicated in Figure 1-1, it would not be prudent to design for the present level of contamination without considering safety factors to account for possible future increases; as well as experimental test data.

It cannot be determined with any certainty that the contamination level will increase, decrease or even how long it will last. The annual average increase has been approximately 25 ppb per year. In five years and assuming



VOC CONCENTRATION TRENDS

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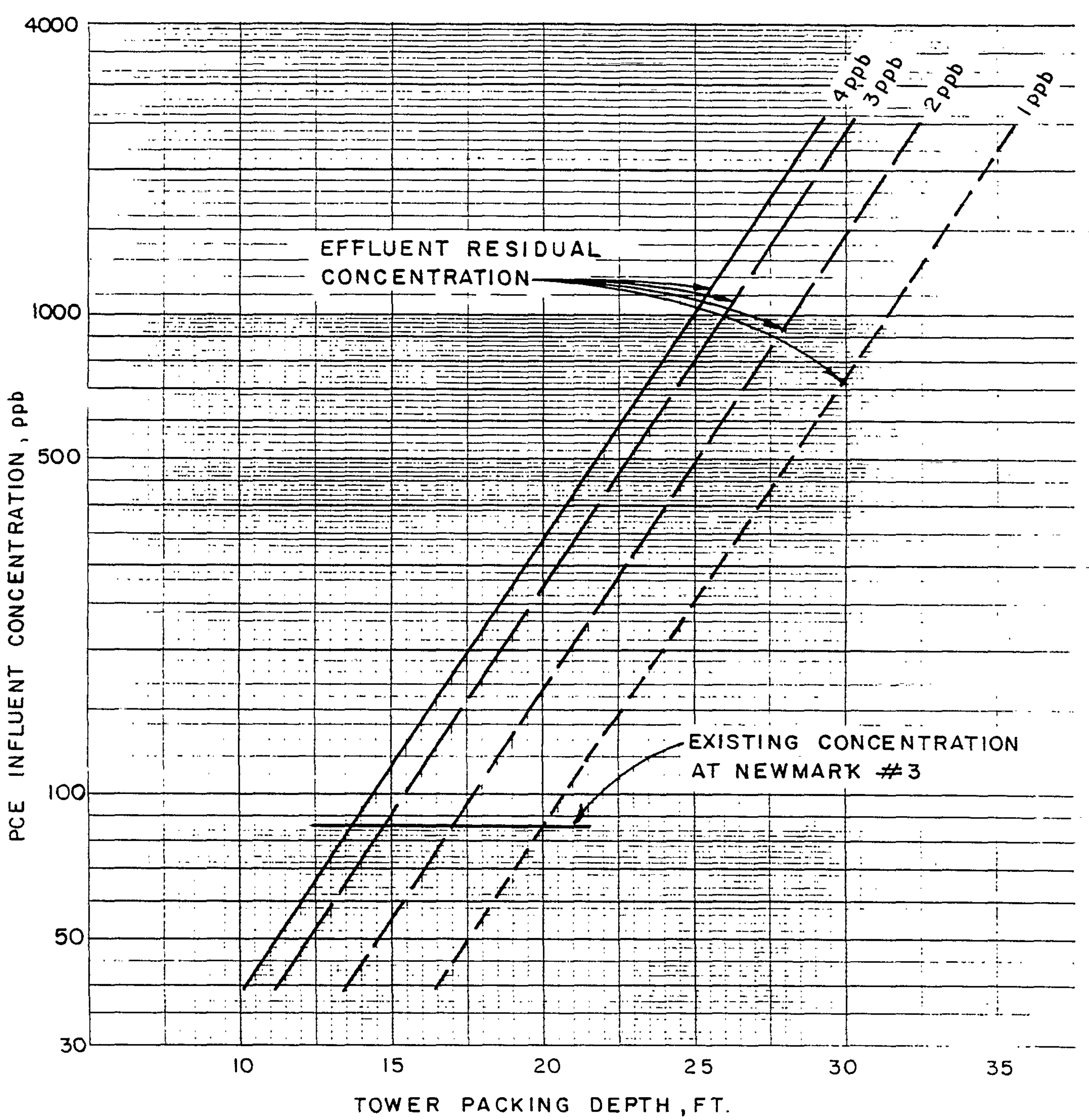
FIGURE 1-1

CITY01604



INFLUENCE OF PCE CONCENTRATION
ON PACKING DEPTH
FOR SPECIFIC EFFLUENT RESIDUALS

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FIGURE 1-2

CITY01605

the above rate, the projected concentration level at Well No. 3 could reach 215 ppb. This level of contamination would require a packing media depth of approximately 21.5-feet. There are three methods that could be used to establish tentative design criteria:

1. Assume a relative rate increase of concentration, and based on a safety factor, establish a maximum future concentration. This is essentially an educated guess.

2. Do not use Well No. 3 at this time.

3. Blend water from Well No. 3 with water from the other wells so that the resultant influent level to the treatment process is reduced.

It should be realized that these are really just strategies to deal with the unknown future.

VOC CHARACTERISTICS

TRICHLOROETHYLENE:[(1)]

Other Names. TCE; 1,1,2-trichloroethylene; 1,2,2-trichloroethylene; trichloroethene; acetylene trichloride; ethinyl trichloride; ethylene trichloride; Triclene; Trielene; Trilene; Trichloran; Trichloren; Algylen; Trimar; Triline; Tri; Trethylene; Westrosol; Chlorilen; Gemalgene; Germalgene; Benzinol; 1,1-dichloro-2-chloroethylene; Blacsolv; Blancosolv; Cecolene; 1-chloro- 2,2-dichloroethylene; Chlorylen; Circosolv; Crawhaspol; Dow-tri; Dukeron; Fleck-flip; Flock-flip; Lanadin; Lethurin; Nalco 4546; Nialk; Perm-a-clor; Petzinol; Philex; Triad; Trial; Trisol; Anamenth; Chlorylen; Densinfluat; Fluate; Narcogen; Narkosoid; Threthylen; Threthylene; Trilen.

Trichloroethylene is commercially produced by chlorinating ethylene ($CH_2 = CH_2$) or acetylene ($CH \equiv CH$). Its use is declining because of stringent regulations; however, it has been a common ingredient in many household products (spot removers, rug cleaners, air fresheners), dry cleaning agents, industrial metal cleaners and polishers, refrigerants, and even anesthetics. Its ubiquitous use is perhaps why trichloroethylene is the organic contaminant most frequently encountered in groundwater.

Conventional Treatment. Two studies were found in the literature in which trichloroethylene was identified and measured before and after conventional water treatment. In both studies, the trichloroethylene concentration in the source was lower than 1 u g/L, but no significant removals were observed through the treatment plant. The literature indicates that aeration is the most cost-effective treatment method.

TETRACHLOROETHYLENE:[1]

Other Names. PCE; perchloroethylene; 1,1,2,2-tetrachloroethylene; tetrachloroethene; Ankilostin; carbon bichloride; carbon dichloride; Didakene; ENT-1860; ethylene tetrachloride; NC1-C04580; Nema; Perawin; Perc; Perclene; PerSec; Tetrales; Tetracap; Tetropil; Antisal; Fedan-Un; Tetlen; Tetraguer; Tetraleno.

Tetrachloroethylene is commercially produced by chlorinating acetylene ($CH \equiv CH$) or 1,2-dichloroethane (CH_2ClCH_2Cl), also known as ethylene dichloride. This solvent is widely used in dry cleaning, textile dying, metal degreasing, and in the synthesis of fluorocarbons. Tetrachloroethylene has been used to apply polyvinyl-toluene liners to asbestos-cement pipe. This solvent leaches into finished drinking water from newly laid pipe, as well as from pipe that has been installed for several years. Tetrachloroethylene concentrations from this source range from a few micrograms per liter to several milligrams per liter, the higher concentrations coming from dead-ends where water flow is not continuous. Specifications placed on new pipe can alleviate this source of contamination, but treatment for existing polyvinyl-toluene lined pipe in the ground is a problem that needs attention.

Conventional Treatment. Although tetrachloroethylene is mainly a groundwater contaminant, it has been found in low, measurable concentrations in some surface waters. In one instance, tetrachloroethylene was monitored before and after coagulation, sedimentation, and filtration, and these processes, it was shown, were ineffective for lowering its concentration. The literature also indicates that aeration is the most cost-effective method of treatment.

BASIN GEOHYDROLOGY

The San Bernardino Valley area, from a geology perspective, is generally bounded by faults on all sides, and is generally referred to, from a water basin perspective, as the Bunker Hill groundwater basin. As discussed in a geohydrology report recently prepared by Rasmussen(2), the basin is bounded to the northwest by the merging of the San Andreas and San Jacinto faults at or near the Cajon Pass. A northeasterly boundary is formed by the San Andreas fault and the San Bernardino Mountains; a southeasterly boundary is formed by the Crafton fault; a southerly boundary is formed by the Loma Linda Hills; a southwest boundary is formed by the San Jacinto fault.

Within the valley area, there are numerous other faults (older) which are buried beneath more recent, unfaulted alluvium and which are not generally visible from the surface. These older faults can and do form effective ground water barriers and can influence the direction and rate of groundwater movement in the Valley. One such barrier (Fault K), which is generally referred to as Barrier K, may have a direct influence on the groundwater in the vicinity of the apparent PCE/TCE plume.

A recent geology report(2) prepared specifically for this PCE/TCE plume issue generally concludes ".... that the plume of contaminants can be expected to move relatively slowly to the southeast until it reaches the young, fresh alluvium and the rapid recharge area in the vicinity of Waterman Canyon-East Twin Creek. This influx of fresh groundwater in larger quantities should deflect the groundwater toward the south and toward the low end of the basin. This should result in a larger increase in the rate at which the PCE/TCE plume moves as soon as it reaches this area."

It is important to note that if and when this rapid movement of the plume does occur, the rapid movement of groundwater to the south would generally expose the plume to many additional wells that extract water for potable use. It is important, therefore, and to the extent possible, to intercept the plume at a higher point in the groundwater basin and extract the water so as to lessen the contamination at downstream wells and treat it.

SECTION 2

PACKED COLUMN AIR STRIPPING PROCESS

GENERAL

If water contaminated with volatile organic compounds (VOC's) is brought into contact with uncontaminated air, some of the VOC molecules will transfer to the air. In the packed column air stripping process, this transfer is facilitated as air and water are continuously replenished and mixed together in a countercurrent flow pattern in the following manner:

1. Contaminated water is pumped to the top of a column, distributed at the top, and cascades down through a bed of packing material.

2. Uncontaminated air is blown in at the bottom of the column and forced up through the same bed of packing material.

3. The best packing materials provide a combination of a large surface area to provide mixing of air and water, contact time for VOC molecules to transfer from water to air, and a large void volume to reduce energy loss of the air system.

4. As contaminated water cascades down through the column, VOC molecules are transferred to the air.

5. Air and VOC's are then released to the atmosphere at the top of the column. The concentration of VOC in air released at the top of the column is generally much less than the original concentration of VOC in water due to the large air to water volume ratio. The concentration of VOC in air is further reduced by dispersion into the atmosphere.

6. The countercurrent flow process provides mixing of the most contaminated air and water at the top of the column and mixing of the cleanest air and water at the bottom of the column. The countercurrent flow pattern provides the highest removal efficiencies possible. Removal efficiencies as high as 99.9% have been achieved using packed columns, but these efficiencies are not usually cost-effective, nor are they required.

The theory of mass transfer in a packed column has been well developed in the chemical engineering literature. Mass transfer theory provides Equation 1, which can be used to predict the required column height (Z_T). There are a total of seven terms required to compute Z_T. The influent concentration (X_T) and desired effluent concentration (X_B) are generally known from the system requirements. For preliminary analysis, Henry's coefficient (H) can generally be estimated from vapor pressure and solubility but should be field verified by pilot scale tests if possible. The operating pressure (Pt) is generally assumed to be 1 atm. The design engineer has the freedom to select the air and liquid loadings (G and L) over a large range. For preliminary analysis, the mass transfer coefficient (KLa) can be estimated using empirical equations.

Equation 1[(3)(4)]:
(Packing Height)

$$Z_T = \frac{L}{KLa} * \frac{R}{(R-1)} * \mathrm{Ln}\ \frac{((X_T/X_B) * (R-1) + 1))}{R}$$

Where: $R = \frac{G}{L} * \frac{H}{Pt}$

Z_T = Packing height (m)

X_T = Concentration at top of packing (u g L^{-1})

X_B = Concentration at bottom of packing (u g L^{-1})

H = Henry's coefficient (atm m^3 H_2O m^{-3} air)

Pt = Operating pressure (1 atm)

G = Air loading (m^3 m^{-2} sec^{-1})

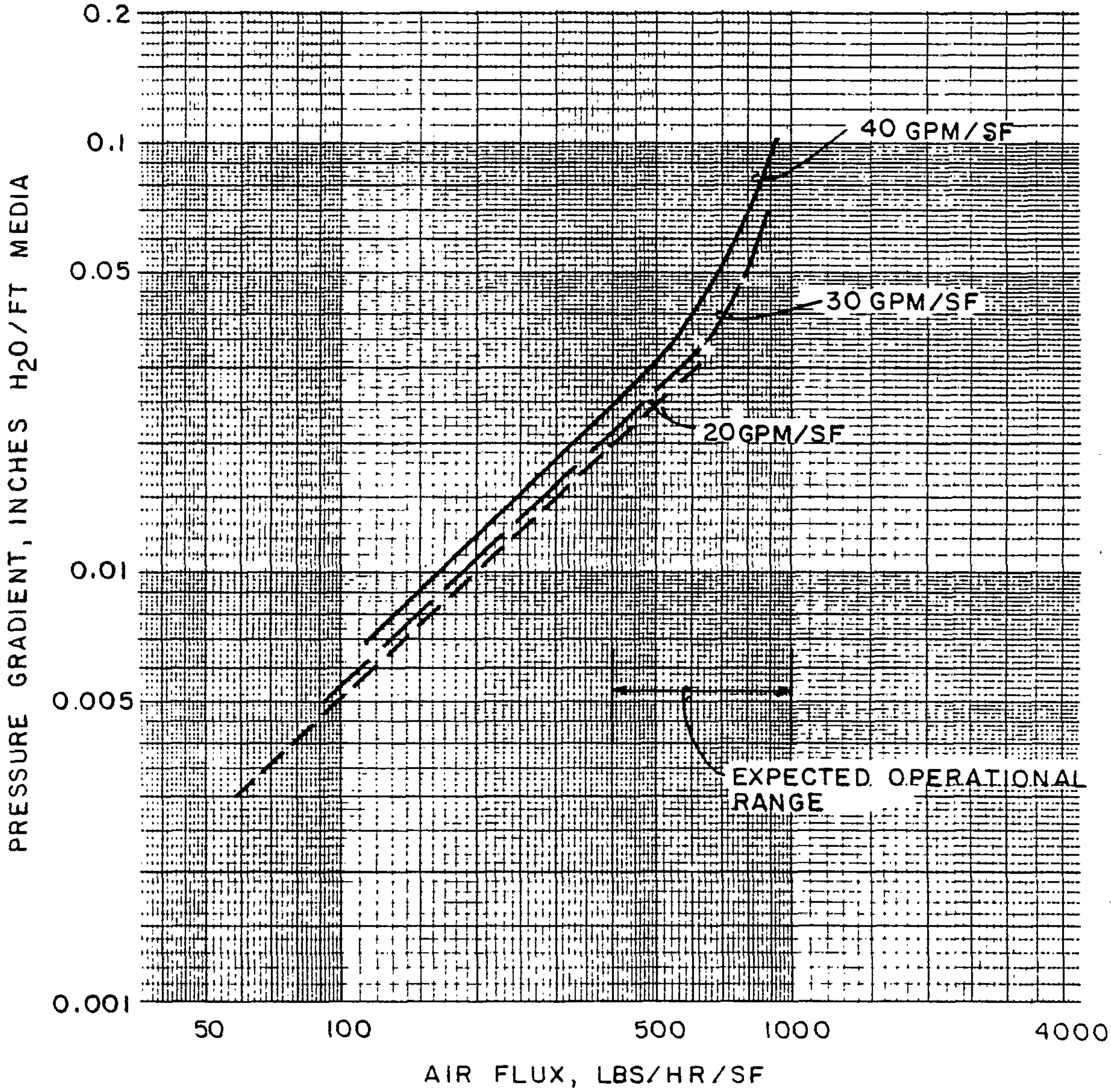
L = Liquid loading (m^3 m^{-2} sec^{-1})

KLa = Mass transfer coefficient (sec^{-1})

The physical size and capital cost of the packed column system will be dependent on the selection of the air and liquid loading point. Thus, the selection of the air and liquid loading point will significantly impact the capital cost of the system. It is possible to locate the air and liquid loading point that results in the least capital cost system, however, the system sizing must also consider the operating cost.

The electrical power consumed by forcing air up through the packed column is the product of the air flow rate, air pressure drop gradient, and packing height. Depending upon the column operating conditions, the air pressure drop gradient can vary over a large range. The air pressure drop gradient through a packed column is a function of both the air loading and liquid loading and is affected by the particular packing media. The media tested in this study had excellent pressure gradient characteristics and should result in minimum pressure losses. There were no observed signs of liquid entrainment or "flooding" as it is also known. The actual air pressure drop gradient for the selected packing is illustrated in Figure 2-1 as a function of air and liquid loading. From Figure 2-1 it can be seen that increasing either the liquid loading or air loading will increase the air pressure drop gradient. Literature indicates that a packed column should not be operated above 1.5-2.0 inches H_2O per foot of packing height. Above this pressure gradient, the downward flowing liquid becomes entrapped in the upward flowing air, resulting in poor removal efficiency and high operational costs.

At higher liquid and air loading rates, the pressure gradient will increase resulting in high electrical power requirements for the blower system; however, the diameter of the resulting packed column becomes smaller. Thus, for a high air pressure gradient, the operating costs are high but the initial capital costs are low. Conversely, selecting lower liquid and air loading rates results in lower electrical power requirements on the blower system and a larger diameter packed column. Thus, for a low air pressure gradient, the operating costs are lower but the initial capital costs are higher. It should be pointed out, however, that the column diameter is more likely to be controlled by the hydraulic loading rate. The most significant air pressure losses are due to the packing media itself.



INFLUENCE OF LIQUID LOADING RATES ON AIR PRESSURE GRADIENT

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FIGURE 2-1

SIMPLIFYING ASSUMPTIONS

The general theory was developed for processes in the chemical manufacturing industry which required a wide range of concentrations, viscosities, and specific gravities. Air stripping volatile organic compounds (VOCs) from a water supply allows the following assumptions that simplify the general theory.

1. The liquid and air volumes do not change due to the VOC's transferred between the two phases.
2. The VOC's obey Henry's law of equilibrium.
3. The influent air supply does not contain VOC's.

The following is presented for air stripping VOC's from a water supply in a counter current flow reactor. The theory is presented in general terms and can be applied to counter current flow reactors which are of interest in the water treatment industry. The chemical engineering mass transfer literature generally expresses concentration as molar ratio. In contrast, the water supply industry conventionally expresses trace organic compounds as u g/L. The following theory is developed using the conventional water supply units of u g/L.

STRIPPING FACTOR

In air stripping of trace volatile organic compounds from a water supply using a counter current reactor, the stripping factor (R), a dimensionless number, is the ratio of the operating air to water ratio to the theoretical minimum air to water ratio required for 100% removal as shown in Equation 2.

Equation 2:

$$R = \frac{(G/L)\ \text{operating}}{(G/L)\ \text{theoretical minimum}}$$

Where:

(G/L) operating = Operating air to water volume ratio
(G/L) theoretical minimum = Theoretical minimum air to water volume ratio for 100% removal
R = Stripping factor

The theoretical minimum air to water ratio can be computed from a mass balance of a counter current column. In an ideal stripping column, the volatile organic compound in the liquid phase enters the column at the top, is completely transferred to the air phase, and exits the column at the top in the air phase. In this ideal column, the VOC concentration in the liquid phase and air phase are in equilibrium according to Henry's law. It can also be shown that the minimum theoretical (G/L) factor (air to water ratio) is the reciprocal of Henry's constant.

In very general terms, it can be seen that the ability to remove a compound also varies according to the values of Henry's constants. The table below indicates the volatile compounds that have been identified in the City well system and the corresponding Henry's constant.

Compound	Henry's Constant (H) at 60° F
Trichlorofloromethane	5.0
Difluorochloromethane	1.2
Tetrachloroethylene	0.83
Trichloroethylene	0.30
Toluene	0.23
1,1-Dichloroethane	0.19
Xylene	0.18
Methylene Chloride	0.087
cis-1,2-Dichloroethylene	0.070

The compound with the lowest value of (H) is the most difficult to remove and will usually control the design criteria (depending on the relative concentrations of each individual compound and the effluent residual that may be required).

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PACKING HEIGHT

The packing height is obtained by Equation 1 which is repeated below:

$$Z_T = \frac{L}{KLa} * \frac{R}{(R-1)} \text{ Ln } \frac{((X_T/X_B) * (R-1)) + 1}{R}$$

The term L/KLa is conventionally referred to as the height of a transfer unit (HTU). The remainder of the right-hand side is conventionally referred to as the number of transfer units (NTU).

$$HTU = \frac{L}{KLa} \qquad \text{Equation 3}$$

$$NTU = \frac{R}{(R-1)} \text{ Ln } \frac{((X_T/X_B) * (R-1)) + 1}{R} \qquad \text{Equation 4}$$

The data from the pilot test unit are used to compute the NTU and HTU. Once HTU is known, the required height of the full scale unit can be computed for any desired removal efficiency.

SECTION 3

STATE ACTION LEVELS

The USEPA has developed documents relating to the health effects of certain volatile organic chemicals in the water supply. The acceptable concentrations are referred to as SNARL's (Suggested No Adverse Effects Levels) and are directly related to an excess cancer risk level of one in one million. The State of California believes that these SNARLS's will eventually become maximum contaminant levels (MCL's). In anticipation of future USEPA action, the State of California Department of Health Services (DHS) established its own criteria, called "ACTION LEVELS."

The State has established "ACTION LEVELS" for both TCE and PCE at the one in a million excess cancer risk concentrations rounded to the nearest whole number:

Constituent	Action Level, ppb
Trichloroethylene (TCE)	5
Tetrachloroethylene (PCE)	4

These ACTION LEVELS are set at the bottom edge of the EPA SNARL'S and represent a conservative estimate of the eventual standard (MCL). We anticipate that they will remain in effect until new State or EPA information is developed. The current list of Action Levels recommended by the DHS is included in Appendix B.

SECTION 4

DISCUSSION OF TEST RESULTS

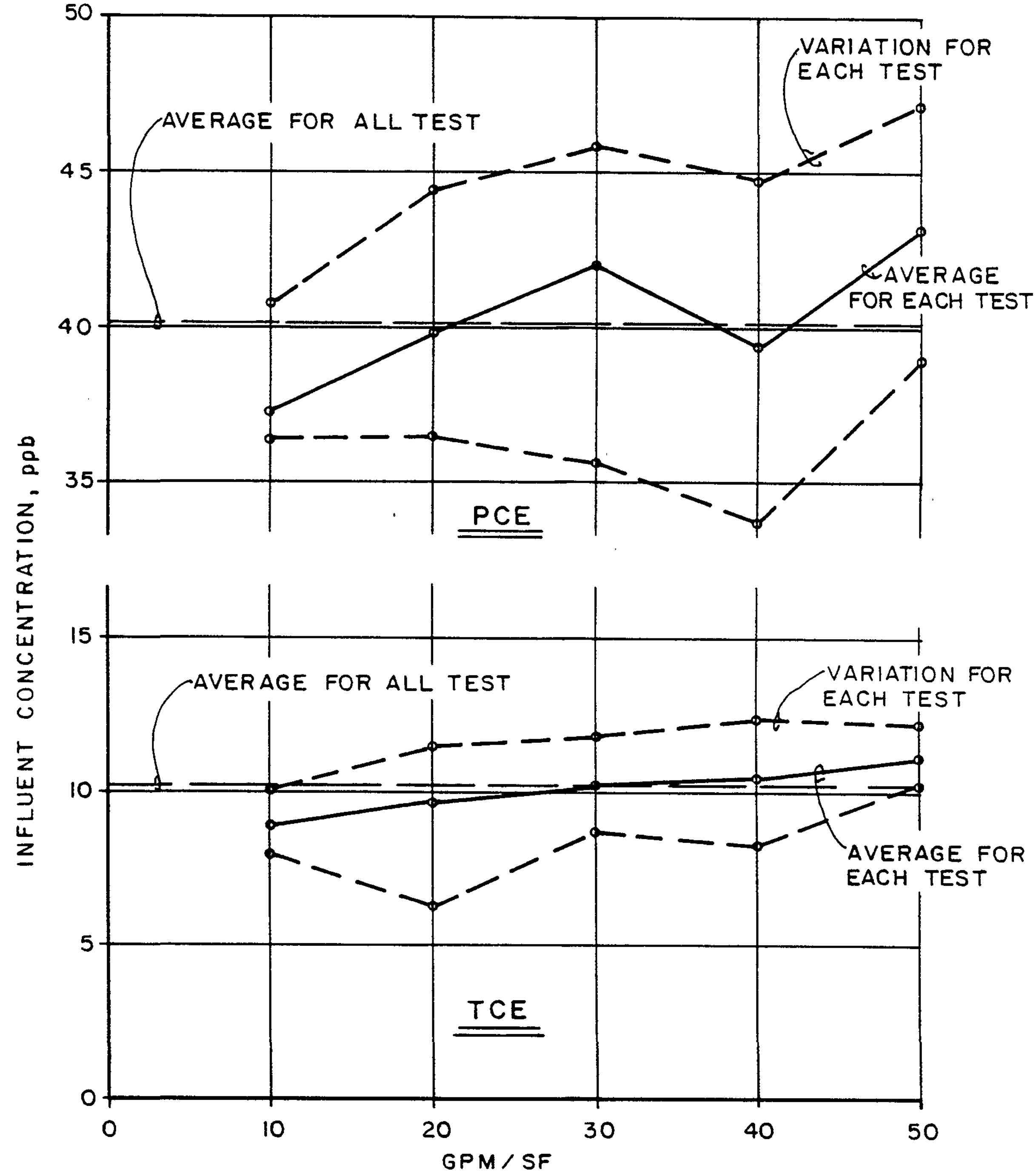
OBJECTIVES

The pilot scale tests were necessary to evaluate the actual design parameters as compared to "published" parameters and to evaluate VOC concentrations for the worst two wells. This included the following:

- Range of VOC concentrations and temperature
- Overall percent removals of VOC's
- Effects of air to water ratio
- Effects of hydraulic loading rate
- Value of mass transfer coefficients at various data points
- Actual pressure loss gradient through the column at various air and water loading parameters
- Estimated height of the packing tower for each condition

DISCUSSION

VOC CONCENTRATIONS: The concentration of influent TCE and PCE was monitored during the test period. The TCE and PCE concentration at both Wells No. 1 and No. 3 varied considerably at each data point (test condition). The variation from maximum to minimum during any one test run was also inconsistent. PCE, in particular, showed significant variations. This data is depicted in Figures 4-1 and 4-2. It was concluded that it is absolutely necessary to sample and analyze the influent for all test conditions. It would be desirable if the number of influent samples could be minimized because of the high cost for the laboratory analysis, however, if individual samples were not collected the entire pilot program would have been worthless.



WELL #1
VARIATION DURING TEST PERIOD
SAN BERNARDINO

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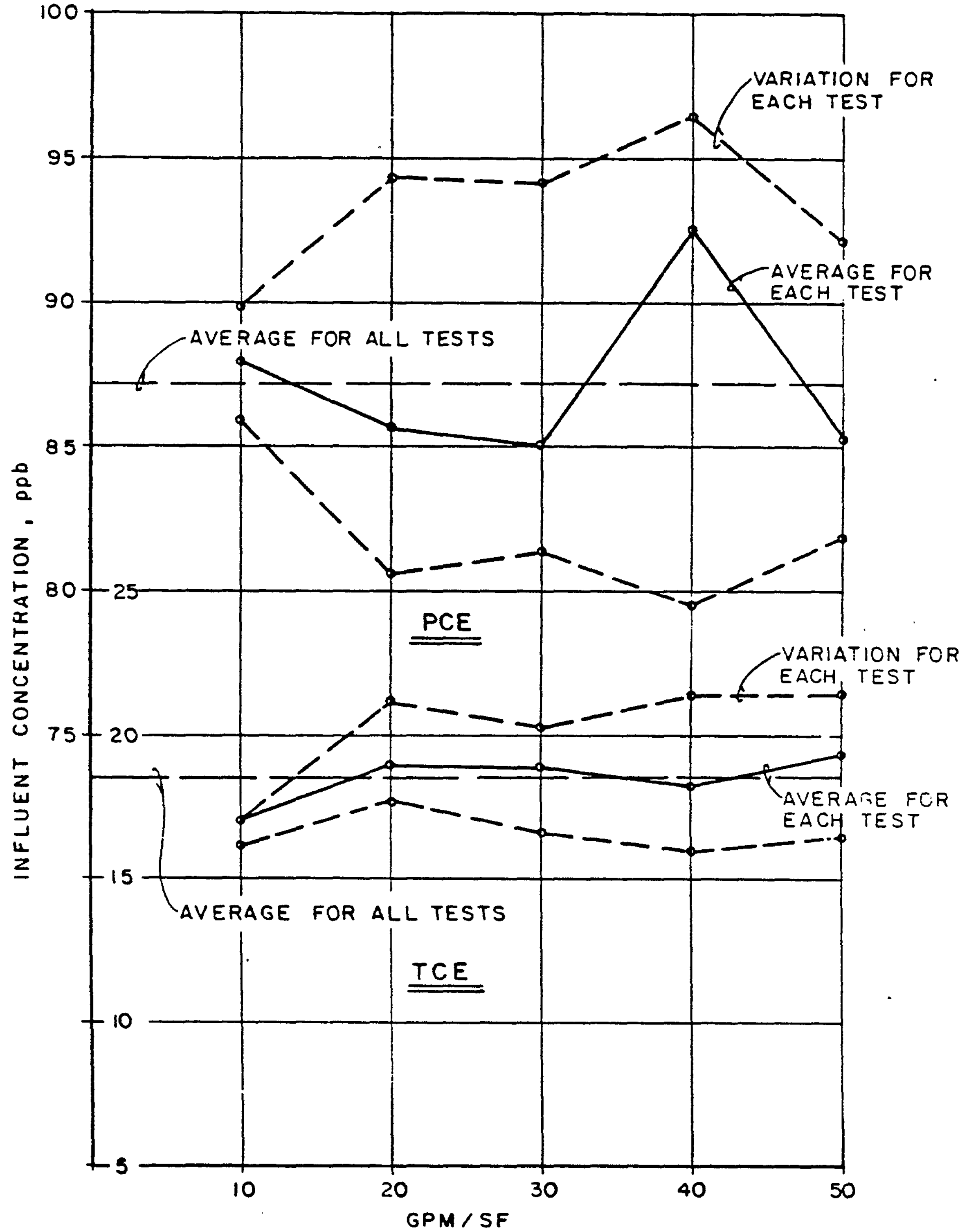
FIGURE 4-1

CITY01619



WELL #3
VARIATION DURING TEST PERIOD
SAN BERNARDINO

United States Summary Judgment Motion, Ex. 50, Page 442

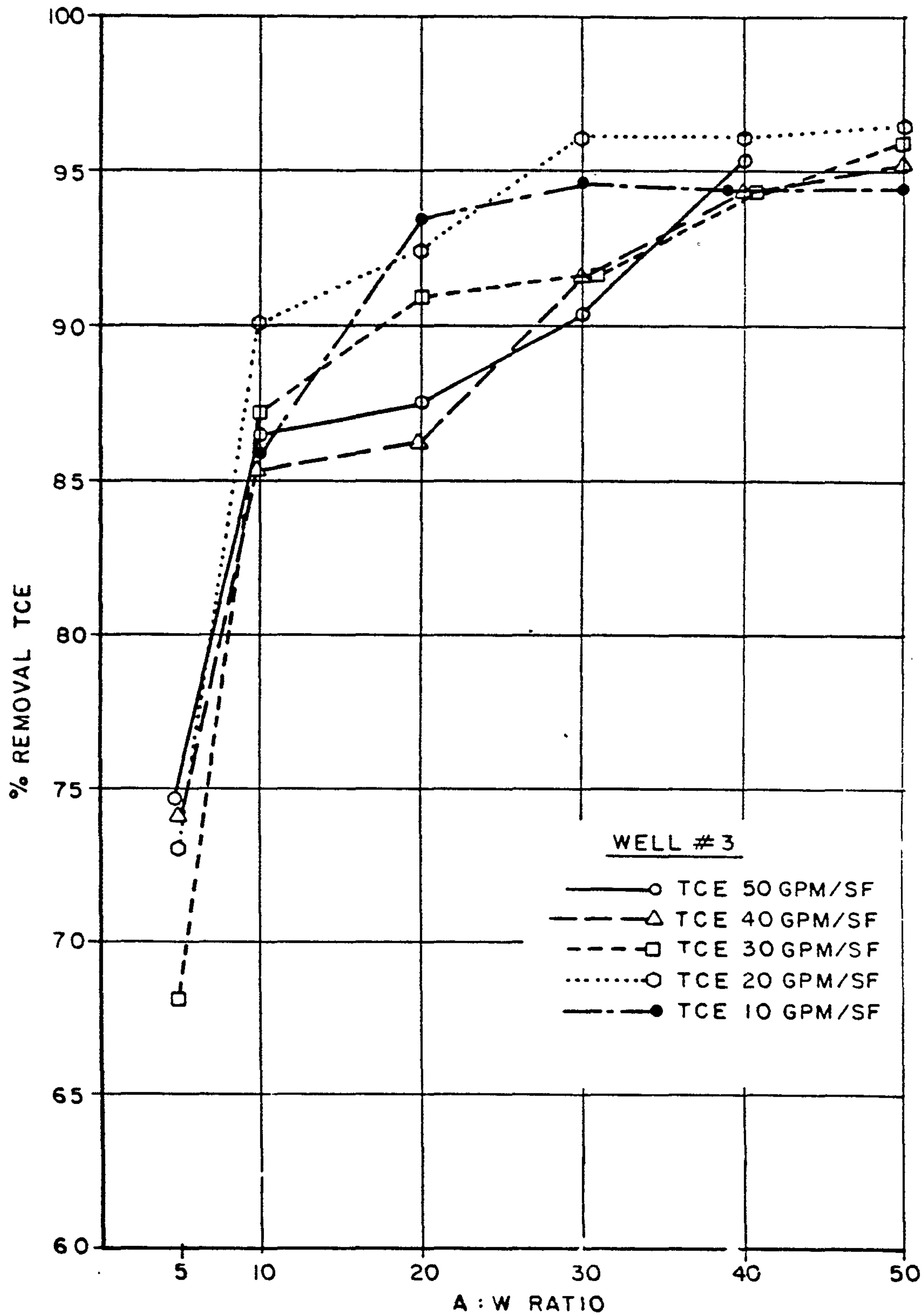
FIGURE 4-2

CITY01620

REMOVAL EFFICIENCY: The pilot data indicate, as expected, that there is a relationship between the removal efficiency of the packed column which depends on the air to water ratio and the hydraulic loading rates. These trends are well defined on Figures 4-3 and 4-4. The numeric value of each data point are contained in a separately bound appendix. In general, the lower the hydraulic loading rate, the higher the overall removal efficiency, at any given air to water ratio. At air to water ratios less than 20:1, the removal efficiency is considerably less than for the higher air to water ratios. It should be noted that the benefits of increased air quickly taper off as is demonstrated by the flattening of the curves. Data for Well No. 1 were not plotted because the laboratory results for the effluent concentration were not reported in sufficient detail for values that were less than 1 ppb. In other words, an exact percent removal could not be calculated because it is not known how much less than 1 ppb the values actually were. All that is really known from those data points is that the towers worked very well. It just cannot be quantified as to how well. The other data from Well No. 1 were checked against the Well No. 3 values and there is a consistency in the data.

It was not expected that the PCE would be more difficult to remove than TCE because this is inconsistent with Henry's Law. Well No. 3 demonstrated this at all the data points. Well No. 1 demonstrated this at only the higher hydraulic loading rates. The differences could be explained by the particular site conditions, temperatures, or molecular diffusivity. It should be noted that the diffusivity coefficient of PCE in water is about 10-15 percent lower than for TCE.

For design purposes, the removal efficiency must be addressed from a different perspective. There are two factors which directly effect the design. First, what effluent concentration should be used? Designing for the



WELL #3

TCE/PCE PILOT TESTS

SAN BERNARDINO

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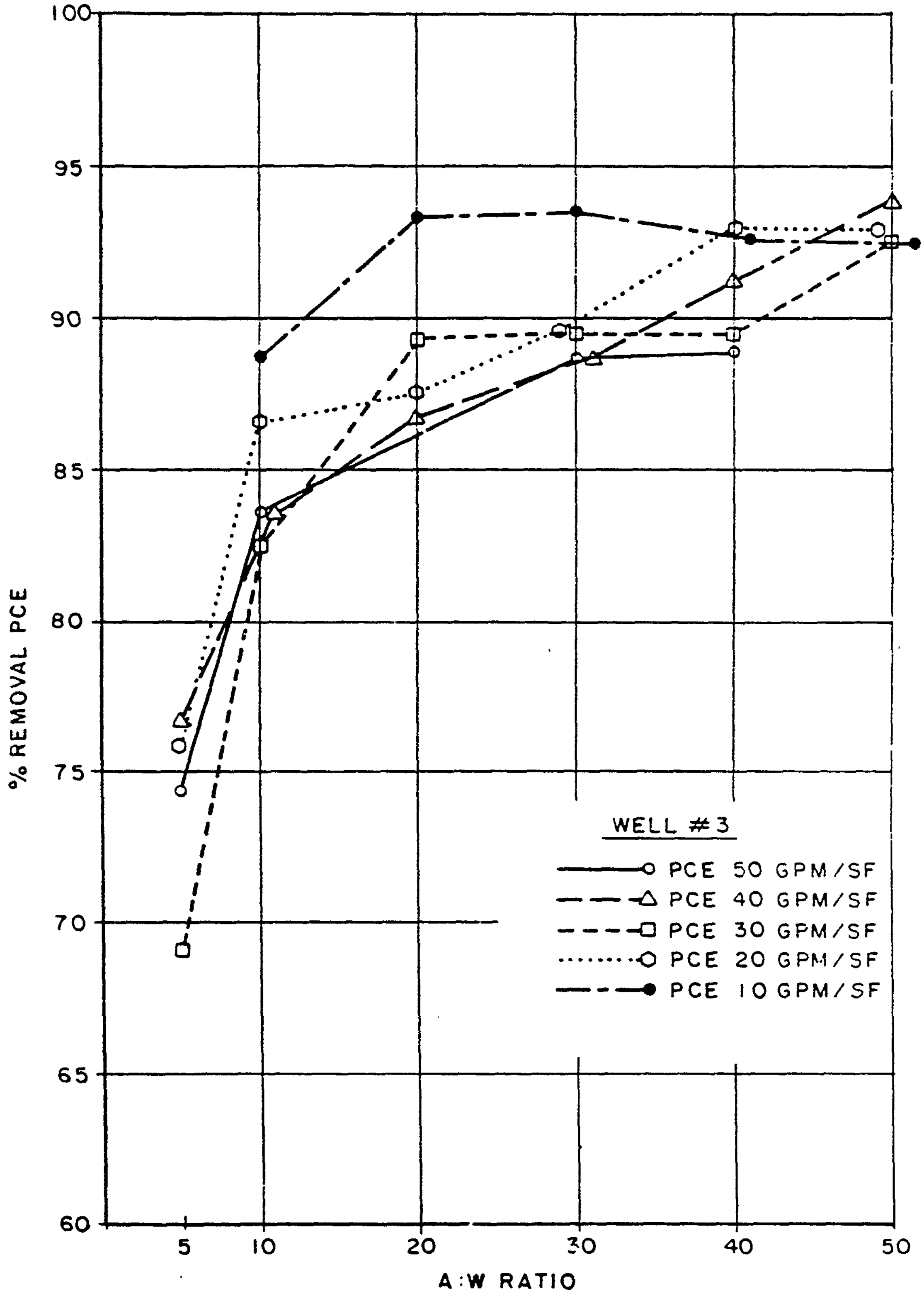
FIGURE 4 – 3

CITY01622



WELL #3

TCE/PCE PILOT TESTS

SAN BERNARDINO

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FIGURE 4-4

CITY01623

value of the SNARL would not allow any safety factor for unforeseen circumstances. The safety factor in tower design generally is influenced more by the height of packing than by any other factor. Unfortunately, the height increases exponentially with the increase in percent removal!

The second factor relates to the value of the influent concentration that can be expected. The data developed for all the design considerations presented herein are based on the current VOC concentrations in Newmark No. 3 with no safety factors assuming the tower treats only unblended water from Well No. 3. Figures 4-5 and 4-6 depict the design removal efficiencies that would be required at each well based on concentrations that exist today for various values of effluent concentration. It is clear from this data that the Well No. 3 PCE concentration (required percent removal) will control the design of the stripping tower. Again, this assumes no blending. To meet the SNARL of 4 ppb requires 95.2 percent removal; 3 ppb requires 96.5 percent; 2 ppb requires 97.5 percent; and 1 ppb requires 98.5 percent.

Once the percent removal criteria are established for PCE removal, the other VOC's should also be removed by approximately the same percentage.

PACKING HEIGHT: The effects of various parameters on the packing height for Well No. 3 are demonstrated by Figures 4-7, 4-8, and 4-9. These figures were prepared to show the required height of packing for both TCE and PCE removal. It is apparent that the PCE controls the height of the tower. Each figure also depicts the effects of various air to water ratios and removal efficiencies for a specific hydraulic loading rate. From Figure 4-7 (20 gpm/sf), the air to water ratio has a pronounced effect on the tower height for a specific removal efficiency (effluent concentration). Figures 4-8 (30 gpm/sf) and 4-9 (40 gpm/sf) demonstrate that the air to water ratio has very little effect on required packing height, but that the towers are slightly

TCE REMOVAL

Required Efficiency

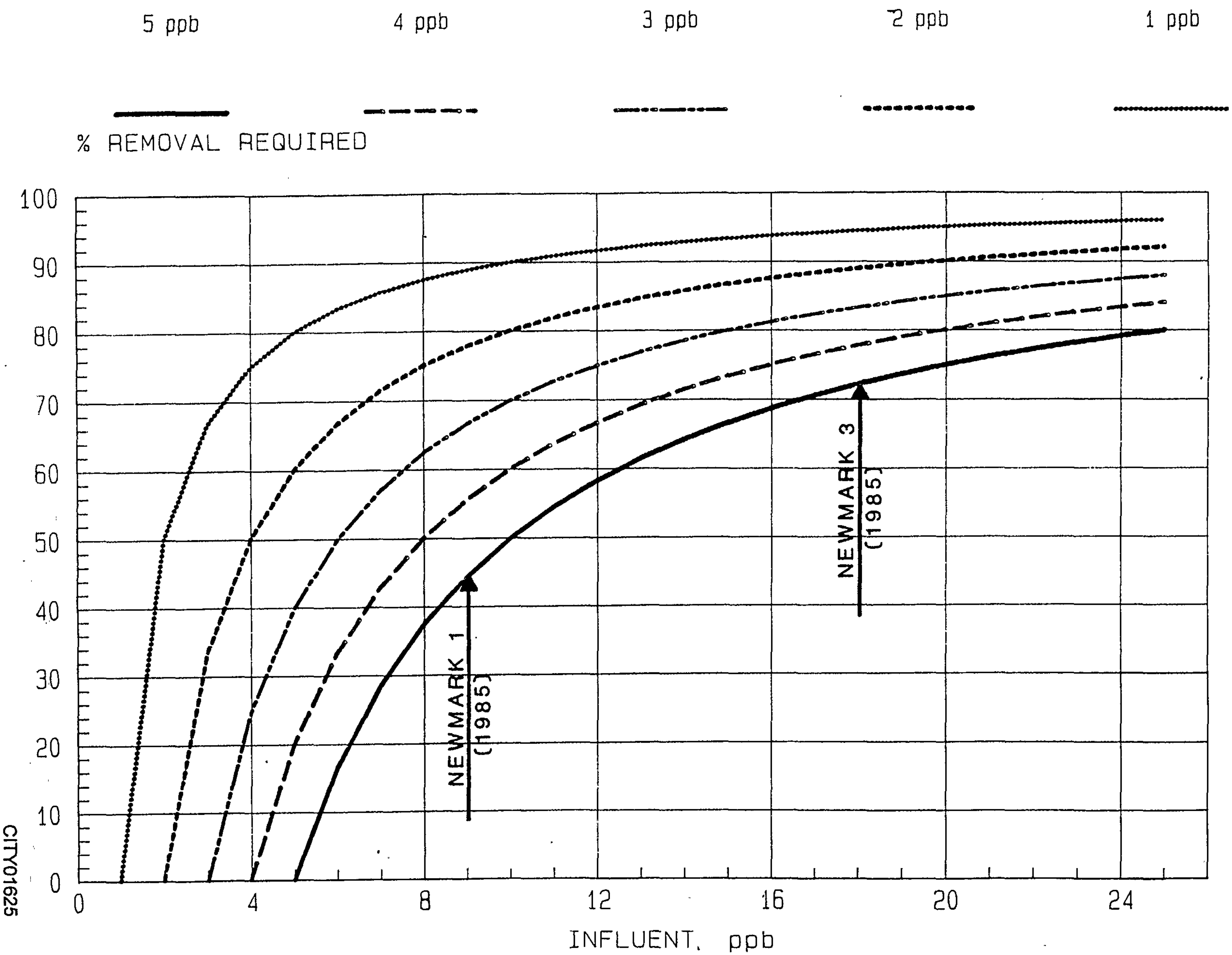

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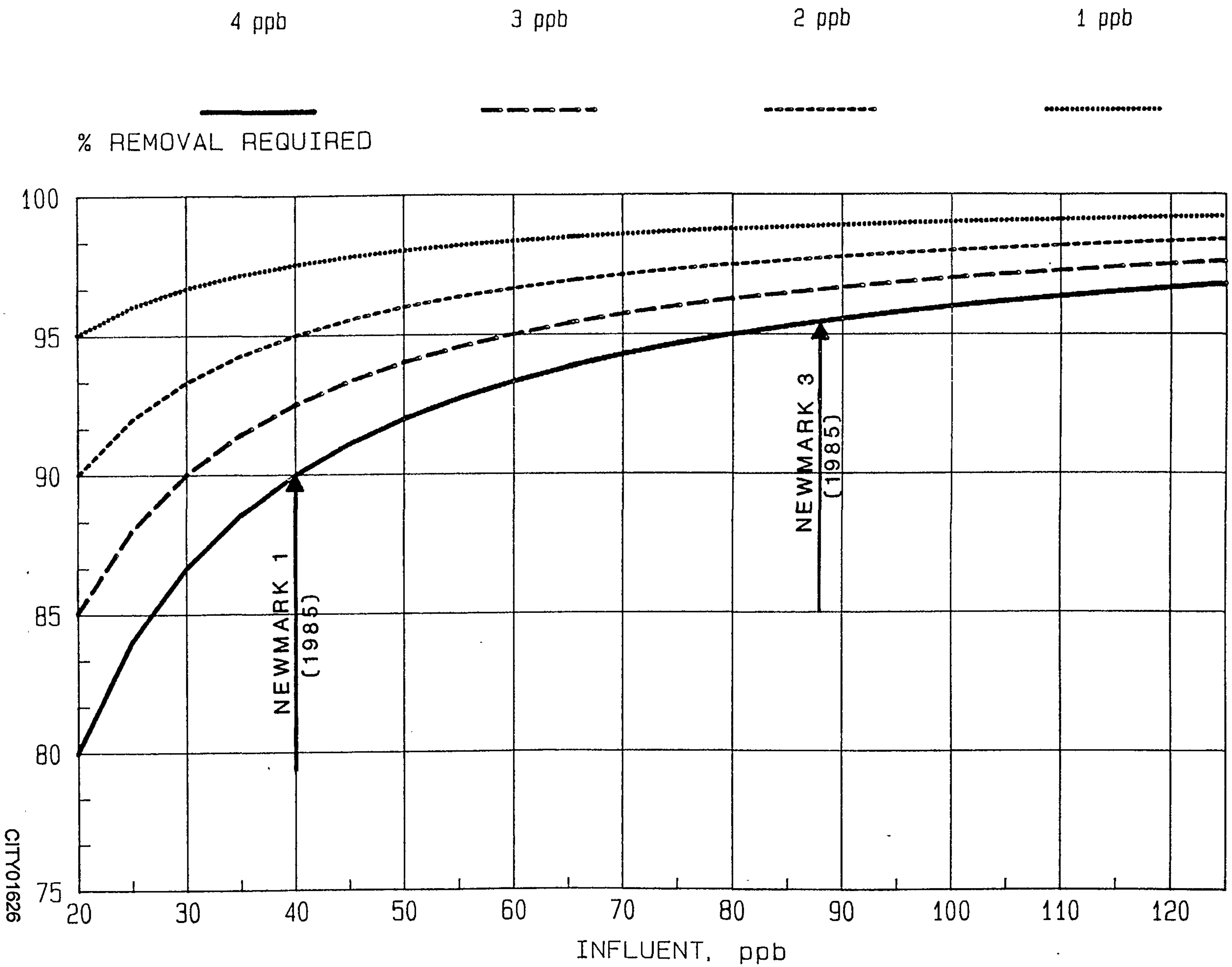
FIGURE 4-5

PCE REMOVAL

Required Efficiency

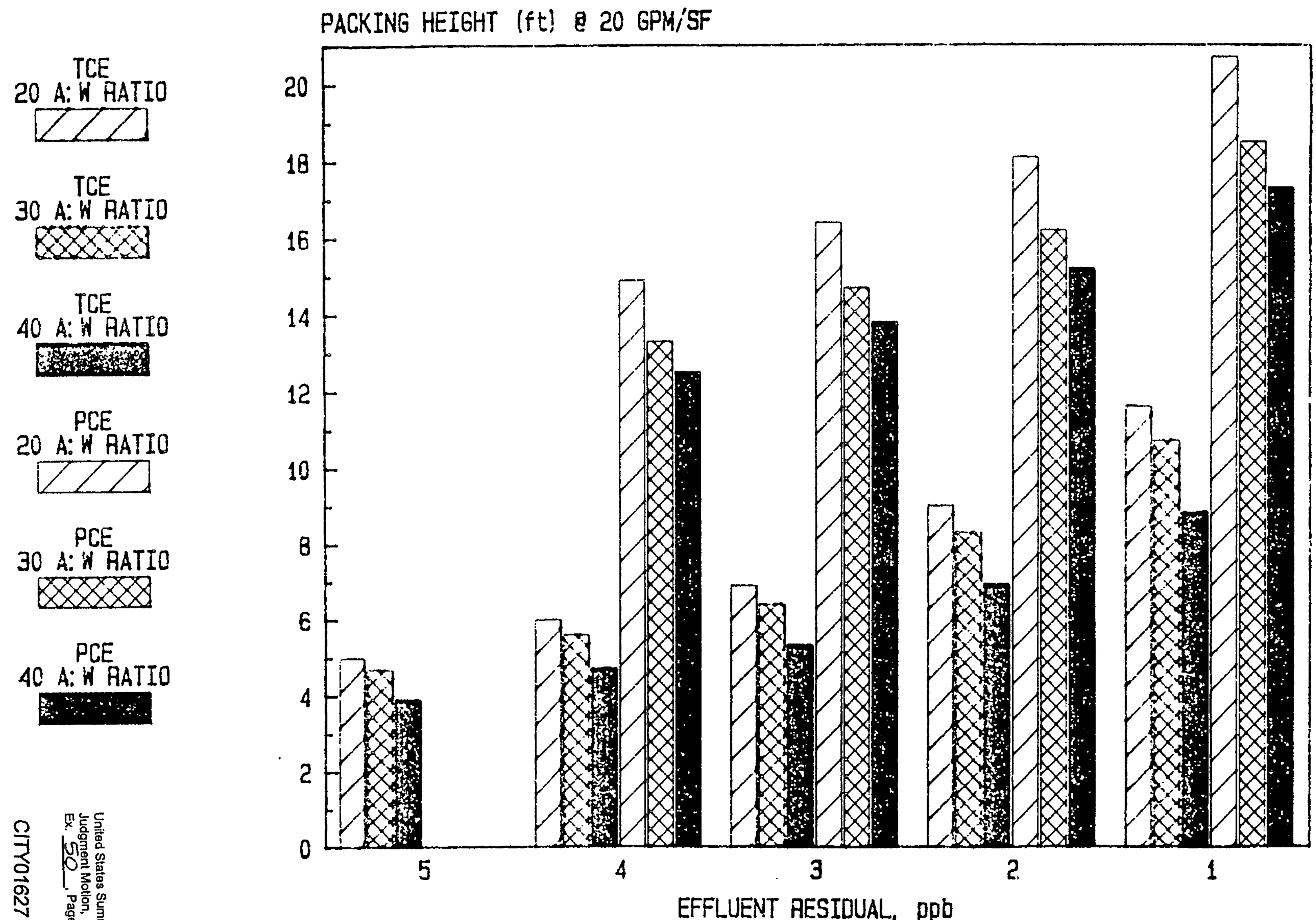


CITY01626

FIGURE 4-6

WELL #3 REQUIRED PACKING HEIGHT

(At Existing Concentrations)



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CITY01627

FIGURE 4-7

WELL #3 REQUIRED PACKING HEIGHT

(At Existing Concentrations)

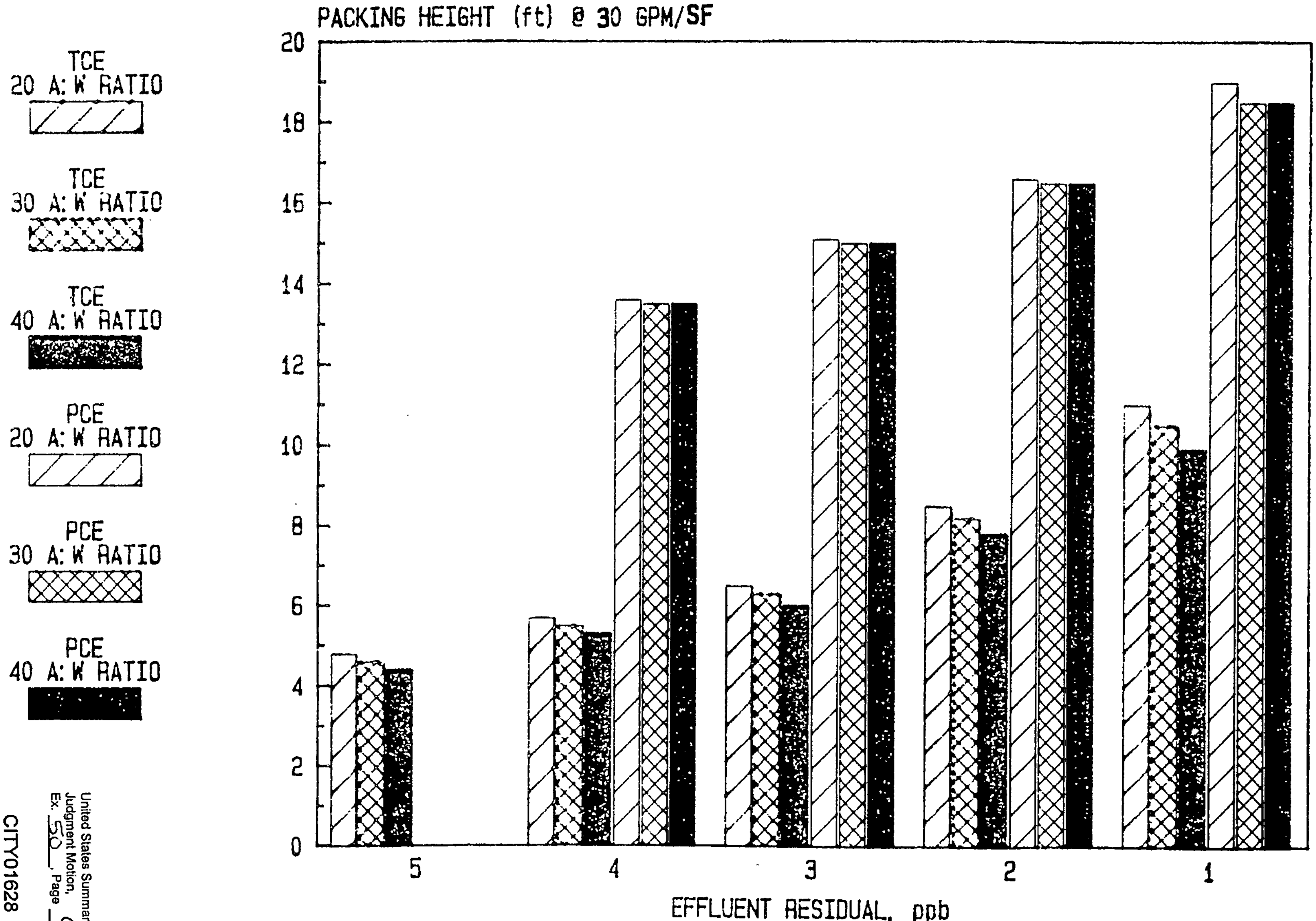


FIGURE 4-8

WELL #3 REQUIRED PACKING HEIGHT

(At Existing Concentrations)

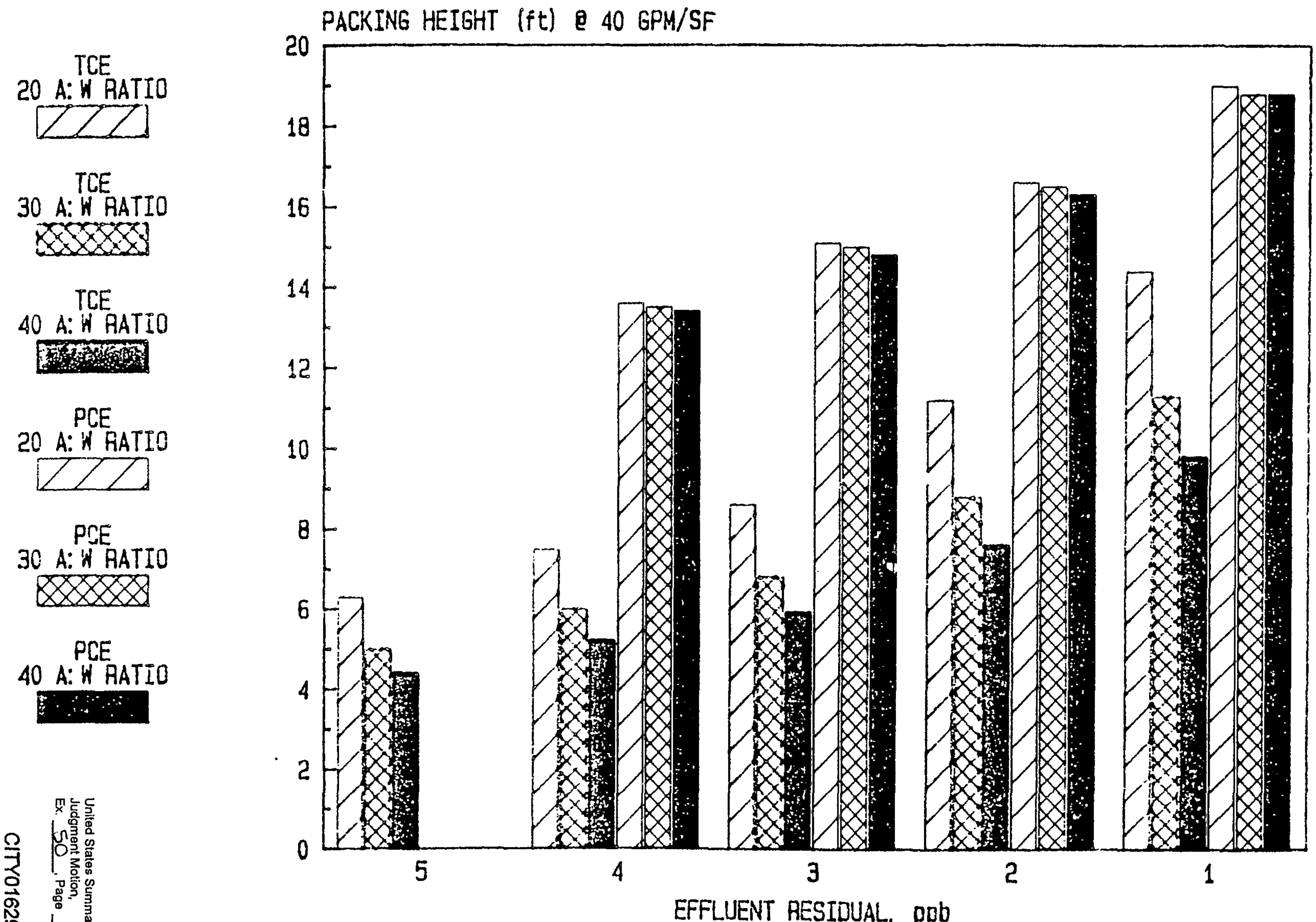


FIGURE 4-9

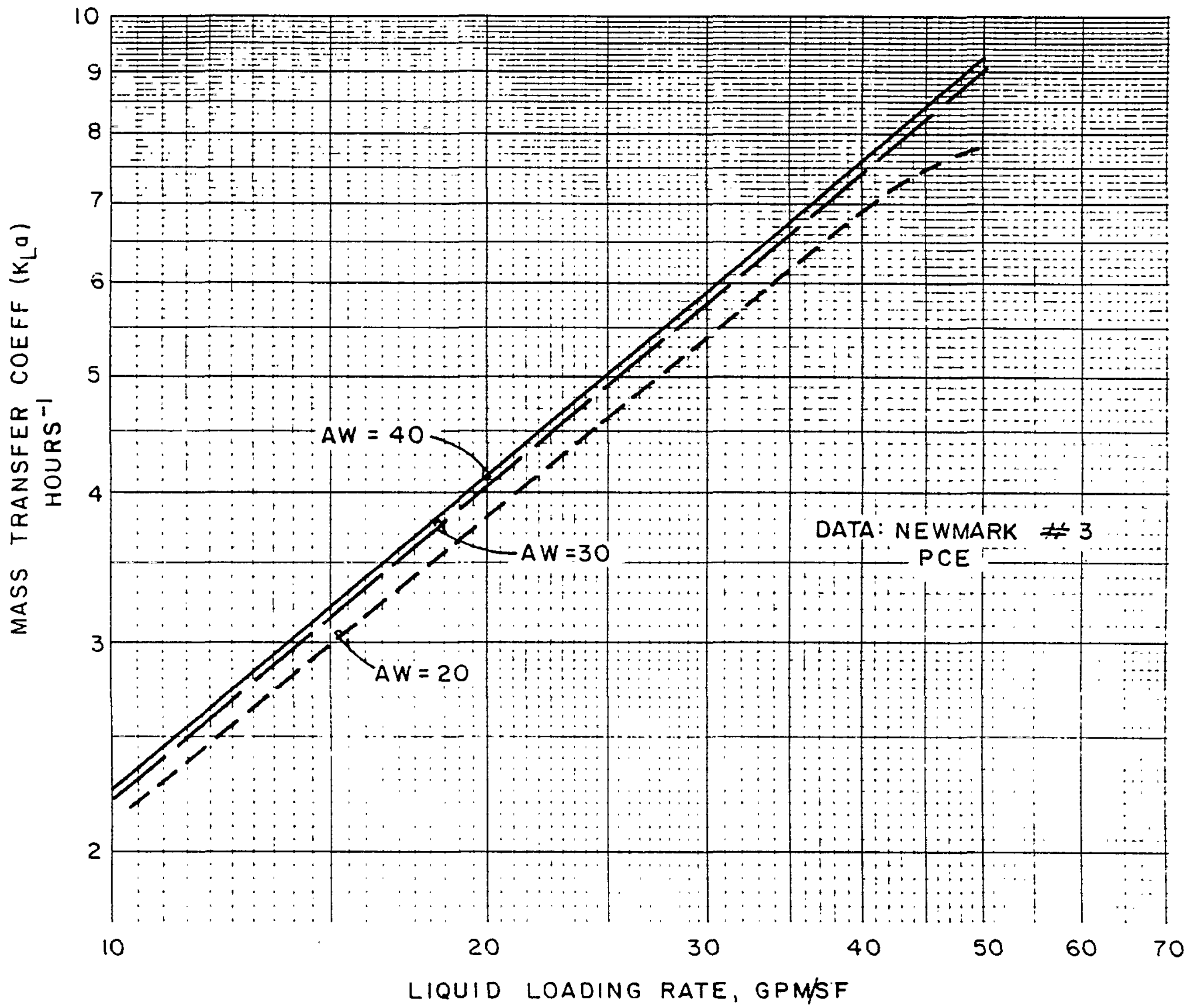
higher to achieve the same removal efficiency. It is also apparent from these figures that the tower height increases considerably depending on the selected safety factor(s) or design effluent concentration. For example, Figure 4-8 indicates that a 13 foot tower would remove sufficient PCE to exactly meet the SNARL of 4 ppb. A desired effluent concentration of 1 ppb would require an approximate tower height of 19 feet. It is also interesting to note that the tower heights are approximately the same for the hydraulic loading rates of 30 and 40 gpm/sf.

It could be concluded that at a liquid loading rate of at least 30 gpm/sf the air to water ratio is not particularly critical over the range of 20:1 to 40:1. This apparent lack of sensitivity would be desirable from an operational viewpoint.

MASS TRANSFER RELATIONSHIPS: To use the results of the pilot test data, VOC mass transfer relationships were developed for Newmark No. 3 PCE data. For each data point, the height of a transfer unit (HTU) and the mass transfer coefficient (KLa) were calculated from the water flow rate, air to water ratio, temperature, and percent removals that actually occurred. A plot of the mass transfer coefficient for PCE versus water flow rate is shown on Figure 4-10. This data indicates that KLa increases with the water loading rate and is influenced by the air to water ratio. The lowest air to water ratio has the lowest KLa at any given water rate.

It is also noted that for an A:W of 30 to 1 and 40 to 1 there is very little difference in the mass transfer coefficient once a column is operating near its optimum values. The A:W of 20:1 is not as close to the optimum value as the other values and will not be considered for final design

Figure 4-11 demonstrates the impact of the A:W ratio on the heights of transfer units (HTU). It should be noted that tower height is a function of



INFLUENCE OF LIQUID LOADING RATE ON MASS TRANSFER RATE AT SPECIFIC AIR:WATER RATIOS

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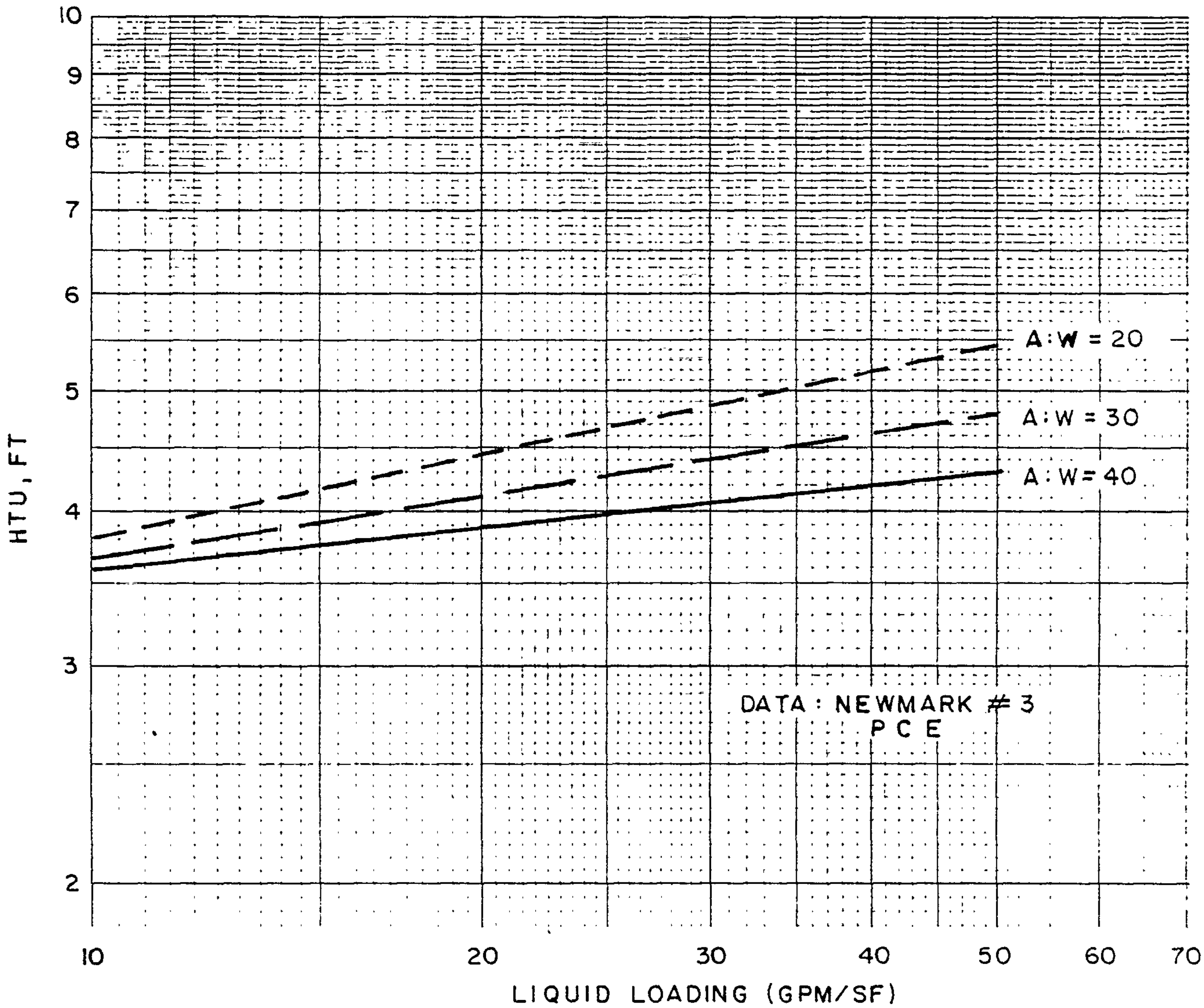
FIGURE 4-10

CITY01631



INFLUENCE OF AIR TO WATER RATIO ON HEIGHT OF TRANSFER UNIT AT SPECIFIC LIQUID LOADING RATES

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FIGURE 4-11

the number of transfer units (NTU) times the height of the transfer units (HTU). The taller the HTU value, the less efficient the removal process; therefore, the taller the ultimate tower would need to be. An A:W of 20:1 demonstrates a definite trend towards less efficient operation (taller towers) as the water rate increases. An increase to an A:W of 30:1 shows the HTU values leveling off at about 45 gpm/sf. At an A:W ratio of 40:1 the HTU values level off at about 40 gpm/sf.

For water rates between 20 and 30 gpm/sf the HTU values do not vary significantly.

SECTION 5

DESIGN CRITERIA

LIQUID LOADING RATE

Previous discussion indicate that liquid loading rates of 20 to 40 gpm/sf appear to be reasonable. Figure 5-1 depicts the effect of liquid loading rate on the cross sectional tower area and the actual size required for a tower operating at 2,000 gpm. As the liquid loading increases, the reduction in tower cross section becomes less significant. A design rate of 30 gpm/sf is suggested for the prototype design.

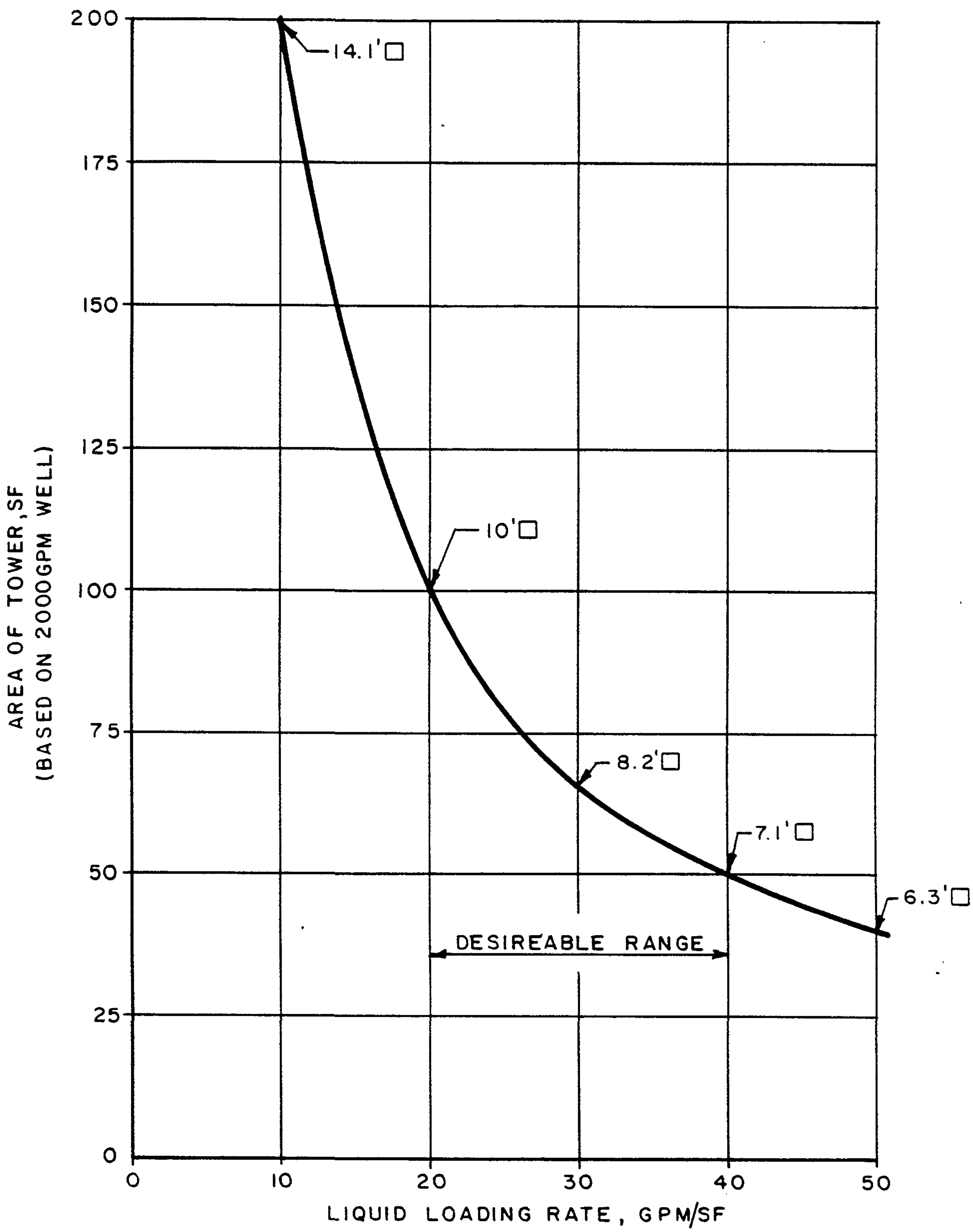
Figure 5-2 depicts the influent versus the volume of media required as a function of the liquid loading rate. This data is based on a 20 foot packing height operating at 2,000 gpm.

AIR TO WATER RATIO

Previous discussions based on removal efficiency only, indicate that at a ratio above 30:1 there is no significant increase in removal efficiency. On the basis of power costs, it is advantageous to select the lowest A:W ratio that will satisfy the mass transfer relationships. The suggested A:W ratio has been selected at 30:1.

BASIS OF DESIGN

The following design criteria are based on the PCE data for Newmark No. 3.



INFLUENCE OF LIQUID LOADING RATE ON CROSS SECTIONAL TOWER DIMENSIONS

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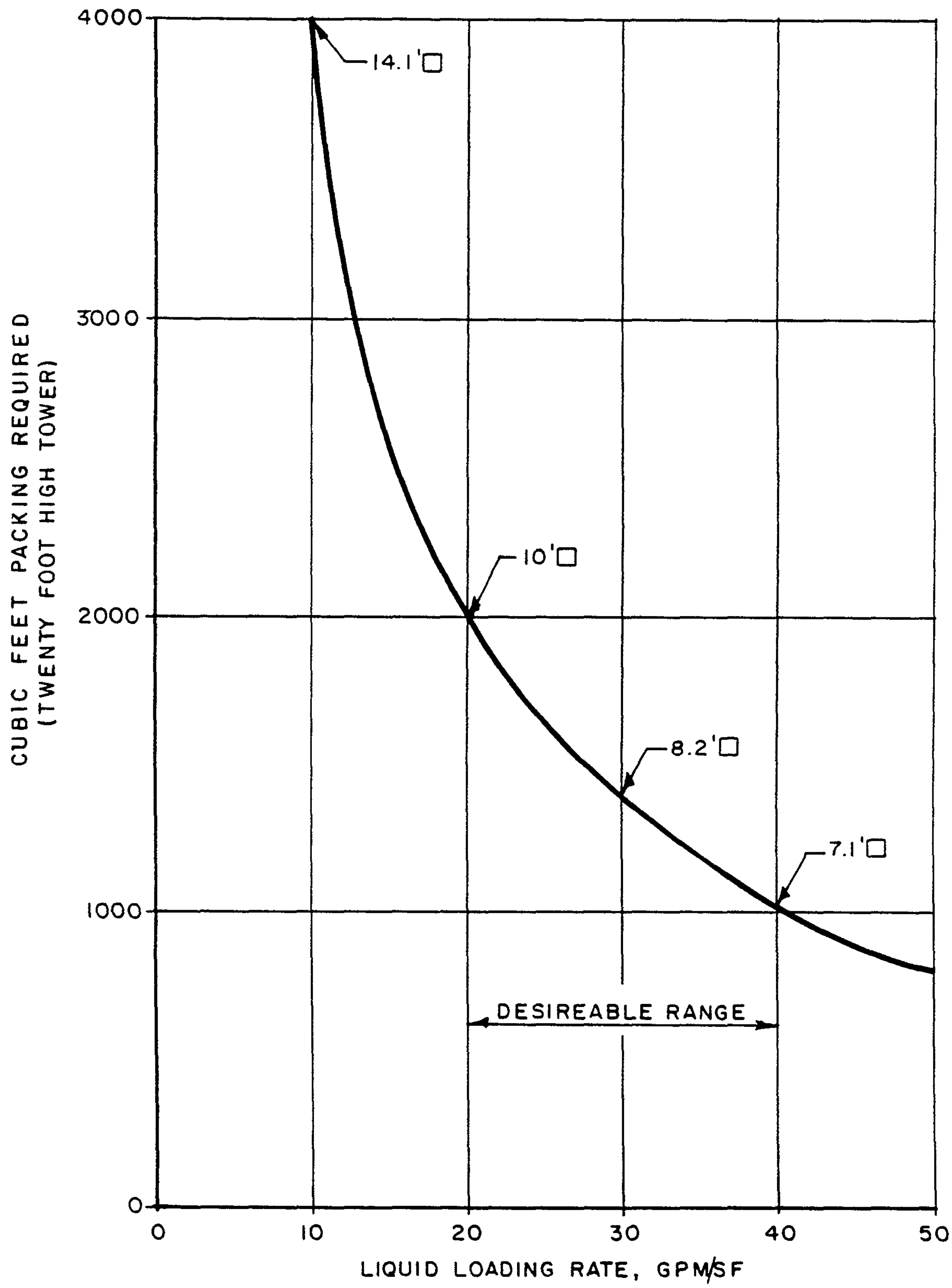
FIGURE 5-1

CITY01635



INFLUENCE OF LIQUID LOADING RATE ON VOLUME OF PACKING REQUIRED

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FIGURE 5-2

Flow rate	2,000 gpm
Hydraulic loading rate	30 gpm/sf
Number of towers	1
Dimensions	8 foot square or 9-foot Ø
Packing height to produce 2 ppb PCE	21.5 feet
Air:Water ratio	30:1
Influent PCE Concentration	200± ppm

The above general design criteria are for information purposes only, and are subject to changes as the design of the prototype proceeds. Factors that would have an impact on the final design criteria, as a minimum, would include the number of wells operating at one time, the level of contamination of each well, the City's operational procedures and/or limitations, desired safety factor; etc.

At this point in the design process, we certainly believe that final design can now progress. Meetings should be held with affected State agencies; etc., to advise interested parties of the City's proposed program(s) and successes.

SECTION 6

COSTS

COSTS

As stated heretofore in the report, the number of towers will depend on the City's selected operational methodology. This type of decision will also affect costing of the facilities. For example, operational methodology would determine the extent of pipe manifolding required at the site, valving, and flexibility in well selection. Excluding site preparation costs, we estimate that each stripping tower would have an estimated construction cost of approximately $125,000. Included in this cost would be all costs particular to each stripper; i.e., meters, valves, controls; etc. Not included in the costs would be the construction costs to deliver the raw water to each stripper and convey treated water to the reservoir. With regard to site preparation costs, we suggest that the City budget for a cost of $100,000. Site preparation costs would generally include yard piping, valving, base for stripper, building(s) for controls, electrical; etc.

With regard to the Newmark Reservoir site, and assuming that three towers each sized for 2,000 gpm were constructed, the estimated cost would be as follows:

• Three Stripping Towers	$375,000
• Site Preparation	100,000
Total Estimated Construction Cost	$475,000

We suggest that the City budget for $500,000 for the Newmark site. The above would permit the operation of two (2) wells, with a tower available on stand-by. In a tight demand situation, a third well could be brought on-line

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CITY01638

by placing the stand-by tower into operation. An acceptable alternative to the above would be to construct two towers sized for 3,000 gpm each.

With regard to the Waterman Reservoir site, and assuming that two towers sized for 3,000 gpm each were constructed, the estimated cost would be as follows:

• Two Stripping Towers	$250,000
• Site Preparation	100,000
	$350,000

We suggest that the City budget for $375,000 at the Waterman site. As in the former case, one tower would be available on a stand-by basis and could also be placed into full time service.

With regard to operation-maintenance costs, the City can expect routine maintenance on blowers, air filters, meters, controls, and valves. Such equipment should be placed on a preventitive maintenance program. Power costs can and have been estimated assuming full time use of a unit on an annual basis (8,760 hours per year); accordingly:

Power Costs @ $.10 per kwh	$35,000
Chemicals	1,000
Labor - 1/2 hr. per day per tower @ $20 per hour	3,650
	$39,650

We suggest that the City budget for $40,000 per year O&M cost for each tower placed into full time service. The above power costs reflect the blower horsepower requirements as well as additional horsepower requirements to convey the raw water from a well site to the top of the tower.

As the City gains experience with the "system," the City may find it necessary to adjust upward or downward this proposed budgeted figure.

APPENDIX A

REFERENCES

1. "Treatment of Volatile Organics in Drinking Water." EPA - 600/8-83-019, May 1983.

2. "Preliminary Engineering Geology Analysis of Groundwater Movement in the North San Bernardino Area, San Bernardino, CA." Gary S. Rasmussen & Associates, April 1985.

3. Cummins, Michael D. (USEPA), "Removal of Ethylene Dibromide from Contaminated Groundwater by Packed Column Air Strippers." August 1984.

4. Selleck, Robert E. University of California - Berkeley, Personal Communication, 1985.

APPENDIX B

State Department of Health Services
Action Levels Recommended

Chemical	Action Level (pph)
Pesticides	
Chlorinated Hydrocarbon	
Aldrin	Limit of Quantification (0.05)
a-Benzene Hexachloride (a-BHC)	0.70
b-Benzene Hexachloride (b-BHC)	0.30
Chlordane	0.055
Dieldrin	Limit of Quantification (0.05)
Heptachlor	0.02
Heptachlor Epoxide	0.10
Pentachlorophenol	30.00
Organophosphate	
Diamethoate	140.00
Diazinon	14.00
Ethion	35.00
Malathion	160.00
Methyl Parathion	30.00
Parathion	30.00
Trithion	7.00
Carbomate	
Aldicarb	10.00
Baygon	90.00
Phthalamide	
Captan	350.00
Amides	
Diphenamide	40.00
Fumigants	
Dibromochloropropane	1.00
1,2-Dichloropropane	10.00
Ethylene Dibromide	Limit of Quantification (0.05)
Miscellaneous	
Terrachlor (Pentacloronitrobenzene)	0.90

Herbicides	
CIPC (isopropyl N (3-chlorophenyl) carbamate)	350.0
Bolero	10.00 (Tentative)
(thiobencarb)	1.0*
Ordram (Molinate)	20.00
Glyphosate	500.00
Purgeable Halocarbons	
Carbon Tetrachloride	5.00
1,2-Dichloroethane	1.00
1,1-Dichloroethylene	0.2
Methylene Chloride	40.00
Tetrachloroethylene	4.00
1,1,1-Trichloroethane	200.00
Trichloroethylene	5.00
Vinyl Chloride	2.00
Purgeable Aromatics	
Benzene	0.70
1,2-Dichlorobenzene	130.00 (10)*
1,3-Dichlorobenzene	130.00 (20)*
1,4-Dichlorobenzene	130.00 (0.3)*

(Action level for dichlorobenzene is either for a single isomer or for the sum of the 3 isomers)

Toluene	100.00
Ortho-Xylene	620.00
Para-Xylene	620.00
Meta-Xylene	620.00

(Action level for Xylene is either for a single isomer or the sum of the isomers)

Phenols	
2,4-dimethylphenol	400.00*
Phenol	1.00* (For Chlorinated Systems)
Aldehydes	
Formaldehyde	30.00

*Taste & Odor Threshold

Exhibit 51

SAN BERNARDINO MUNICIPAL WATER DEPARTMENT

Inter-Departmental Correspondence

September 13, 1985

TO: Herbert B. Wessel

FROM: Joseph F. Stejskal

SUBJECT: TCE/PCE CONTAMINATED WATER TO EAST TWIN CREEK FLOOD CONTROL CHANNEL

The stilling ponds, located at the end of the City's storm drain, that we are pumping the contaminated water into from the 31st Street Well are ponding and percolating. I have asked Fred to shut the well down. When the ponds dry out, approximately one week with sunshine, we will contract a D-9 size dozer with an operator to construct a high bank narrow channel through the basins.

I think that the risk of contaminating our southeastern wells is too great if we allow the water to percolate at that elevation and location. The 30th Street plant can remain on line since it is dumping into the Mill & "G" Street Channel.

Respectfully,

Joseph F. Stejskal, Director
Engineering-Construction-Maintenance

JFS:eg

cc: J. Bocanegra
P. Squires

DEFENDANTS EXHIBIT 559 FOR ID
BRYAN LUI, CSR NO. 11223
DATE: 6-10-99
WITNESS: STEJSKAL, V. II

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CITY01912

550

75 8/79

Exhibit 52

File: Reservoir Coatings

Ret to Bill

WATER QUALITY PROBLEMS ASSOCIATED WITH RESERVOIR COATINGS AND LININGS

R. Scott Yoo
Water Quality Supervisor
East Bay Municipal Utility District
Oakland, CA 94623

William M. Ellgas
Microbiologist
East Bay Municipal Utility District
Oakland, CA 94623

Raymond Lee
Supervising Chemist
East Bay Municipal Utility District
Oakland, CA 94623

ABSTRACT

Selected reservoir linings and coatings may be a source of water quality problems in finished water reservoirs. For many years the East Bay Municipal Utility District rejected certain lining and coating materials because they:

1. Enhanced the growth of bacteria,
2. Contributed tastes and odors, or
3. Leached organic contaminants into finished water.

From these early and continuing experiences, the District has developed a detailed testing protocol for evaluating the suitability of materials for use in contact with finished water. This paper examines several unusual water quality incidents related to reservoir linings and coatings and traces the development of the District's current materials testing program.

INTRODUCTION

In the United States, reservoir coating and lining materials historically have been ignored as potential sources of drinking water contamination. Recent interest in them coincides with the development of sensitive analytical instruments for the detection of trace levels of organic solvents and with increasing regulatory attention to volatile organic contaminants. It is not surprising then, that the leaching of potentially toxic organic solvents from coated storage tank surfaces is receiving significant attention.

There also is increasing documentation of other water quality problems associated with coating and lining materials[1]. For example, it is reported that some coatings can support bacterial growth[2,3,4] and that solvent leaching contributes to tastes and odors in newly coated or lined storage tanks[5].

Many of these problems may be avoided if potentially troublesome materials are identified in advance. Unfortunately, industry standards do not address water quality problems associated with coatings and linings. In addition, the United States Environmental Protection Agency (EPA) and state regulatory agencies have provided only limited guidance in the use of these materials. EPA does not approve materials for use in contact with potable water and the State of California does not have the statutory authority to develop an approval system. Other states such as New York have published lists of approved coatings, but testing generally is limited to FDA protocols for water soluble extractives and does not address taste and odor, solvent leaching, or bacterial growth support.

In the absence of regulatory guidelines for the use of reservoir coatings and linings, the East Bay Municipal Utility District has developed its own testing protocol for evaluating the suitability of materials for use in contact with potable water. This paper examines several unusual water quality incidents associated with coating and lining materials and describes how the District's current materials testing protocol has evolved from these experiences.

BACKGROUND

The East Bay Municipal Utility District (EBMUD) serves 1,080,000 people in the San Francisco Bay Area of Northern California. The District operates six filter plants. In 1983 the mean daily gross water consumption was 191 million gallons. The principal source of drinking water is Pardee Reservoir located at the base of the Sierra Nevada Mountains in Northern California. The system includes 119 distribution pumping plants, 165 distribution reservoirs and over 3000 miles of pipe. Because of the high quality source water, very low chlorine residuals are maintained in the distribution system (<0.3 mg/L).

During the last ten years, the District has rejected certain construction materials because they supported the growth of bacteria in the distribution system. The first such material identified was a hemp packing material used in fire hydrants. The first evidence to indicate that a coating material could support the growth of bacteria appeared in 1972 in one of the District's distribution reservoirs.

BAYVIEW #2 RESERVOIR

The events that began in the District's Bayview #2 Reservoir in 1972 initiated the research that eventually would lead to the District's ongoing materials testing program.

Bayview #2 Reservoir is a 5 MG welded steel tank. It first was put into service in October, 1969. There was nothing unusual about the tank's construction. A Cellon-treated plywood roof was supported by interior steel columns. The floor, walls, and columns of Bayview #2 were all coated with coal tar coatings to guard against corrosion.

After two years of trouble-free service, the first of a series of bacterial contaminations occurred in June, 1972 (See Figure 1). The solid lines indicate average coliform counts observed during routine bacteriological monitoring of Bayview #2 Reservoir while it was in service. The shaded portions indicate coliform counts observed while the reservoir was valved out (and not turning over). Clearly there was a significant and recurring contamination.

EBMUD laboratory staff suggested that nutrients may have been leached from the interior coal tar coating materials into the water in sufficient quantities to support the growth of coliform bacteria. While investigating this idea, it was discovered that two different coatings had been applied inside Bayview #2. The floor and first 24 feet of wall were coated with a hot-applied coal tar enamel. The upper 8 feet of wall was coated with a coal tar epoxy. If the hypothesis was correct, it would be shown that one or both of these materials were responsible for the observed coliform contamination.

GROWTH SUPPORT TESTS

To test the growth support hypothesis, the laboratory developed the Bacterial Growth Support Potential (BGSP) Test[2]. The procedure includes curing a sample of the coating material on a glass microscope slide; sterilizing the material and immersing it in a flask of sterile, buffered, distilled water; inoculating the flask with a known quantity of bacteria; and monitoring the bacterial populations over a period of five weeks.

The BGSP test is carried out with four different bacteria of which three are coliforms and one is a non-coliform. In the very first tests run on samples of coating materials from Bayview #2, the organism isolated from the contaminated reservoir, *Klebsiella oxytoca*, was used.

Figure 2 exemplifies a typical BGSP test growth curve. The control flasks, which contain only water and the inoculum, often show a gradual die-off of bacteria. Flasks containing coating materials that are growth supportive usually exhibit exponential growth according to classic microbial growth patterns.

Materials are evaluated on the basis of the ratio of population densities observed in the test flask to those observed in the control during a five-week incubation. If the ratio of test to control is greater than 10 to 1, growth is indicated and the material usually is rejected. A neutral response, indicated by a ratio of approximately 1 to 1, is acceptable. A toxic response often is indicated in these tests and is manifested by a ratio of about 0 to 1. Toxic response may be due to the presence of residual solvents. Since this effect can mask the effect of nutrient leaching, all materials are evaluated using three different test conditions.

The first test uses a coating sample prepared according to a standardized air-curing procedure. The second test re-examines the same sample slides used in the first test; if toxic solvents or initial leaching of nutrients are only temporary phenomena, then the results of the second test will not confirm the first. In this way, the material can be judged under conditions simulating the initial filling and dumping of a newly coated reservoir. The third test uses an extended air-cured material to evaluate the effect of longer air-curing on product performance.

Tests performed on coating materials used in Bayview #2 Reservoir indicated that the upper coating (coal tar epoxy) was very supportive of the growth of coliform bacteria, especially *Klebsiella oxytoca*. In 1980, an attempt was made to resolve the problem by painting over the old coal tar coating with a non-growth supportive epoxy material. When this was unsuccessful, it was suggested that nutrients were leaching through the new top coat. A final solution was not attained until the old coatings were completely removed (by sandblasting) and an approved coating was applied to the bare steel walls.

TASTE AND ODOR TESTS

Following the work done on Bayview #2 Reservoir, the District began looking more closely at other coating materials used in its reservoirs.

During BGSP testing of these materials, it was noticed that some of the products imparted significant odors to the water, even after extended curing.

In 1977, the District experienced a severe taste and odor episode in two concrete reservoirs which had been patched with an epoxy putty. Because only a small surface area of putty was exposed, it had been thought that there would be no water quality problems. However, when the cracks had been repaired and the reservoirs returned to service, numerous consumer complaints of taste and odor were received.

Following this experience, all materials used inside District water storage tanks were tested for taste and odor as well as BGSP. The test procedure consists of the following: A slide containing the cured material is prepared (just as in the BGSP procedure). The slide is then exposed to 1 L of taste and odor-free water for two weeks and the taste and odor thresholds are determined.

To simulate the dumping and filling of a newly coated reservoir, a second 2-week test is run on the same slide used for the first test. The second test is critical because it will indicate whether the taste and odor can be eliminated by dumping and refilling the newly coated tank. If this is possible, an operational method of eliminating the problem exists. Coatings that produce more persistent taste and odor problems are rejected.

The criteria for accepting or rejecting coating materials is based on the taste and odor threshold numbers. In general, thresholds less than 10 are passing, while thresholds greater than 20 result in rejection of a material. The middle range is conditional in that a material may be judged acceptable depending on the circumstances of its intended use. For example, if only a small amount of material will be applied and the reservoir will turn over rapidly, a material may be approved even though it produced moderate tastes and odors.

SOLVENT LEACHING

The acquisition of analytical instrumentation for the detection of trihalomethanes (THMs) led to further development of the District's materials testing program. In May, 1978, during routine testing for THMs, it was discovered that the chromatogram of a water sample from a newly coated, 1 MG welded-steel reservoir (Reservoir B) displayed an unusual solvent peak. The peak was subsequently identified as perchloroethylene (PCE). The coating material was a coal tar derivative that previously had passed the District's then existing water quality tests.

The sample from Reservoir B was the only one of several dozen in which PCE was detected. Because it was also the newest reservoir tested, the coating material was suspected as a source of the contaminant. This was confirmed by the coating manufacturer and weekly monitoring of the reservoir for PCE was initiated. Samples also were collected from three other reservoirs known to be coated with the same material. The reservoirs ranged in size from 0.25 to 4.5 MG. All contained PCE.

In monitoring PCE and attempting to minimize its levels, the four reservoirs were operated in a variety of ways with mixed results. Figures 3, 4, 5, and 6 indicate the initial levels of PCE detected in each reservoir and the results of subsequent weekly monitoring.

Following the initial discovery of PCE in Reservoir B, six feet were drained from the tank and the reservoir refilled and sampled again. As shown in Figure 3, this resulted in a dramatic decrease in PCE. A strategy of allowing the reservoir elevation to fluctuate was thus implemented. Radical fluctuation of the surface elevation was possible in Reservoir B because it was the only reservoir in its pressure zone. During the next two years, the average levels of PCE in Reservoir B dropped from about 45 ug/L to less than 10 ug/L. The reservoir was eventually taken out of service in October, 1980, sandblasted, and recoated with another material. It was returned to service with no detectable PCE in February, 1981.

As was the case in Reservoir B, the initial levels of PCE detected in Reservoir R were approximately 50 ug/L. Unlike B, however, R was not the only reservoir in the zone. The District was thus able to drain the reservoir to allow a 6-month period of air-curing. As shown in Figure 4, this was effective in reducing the levels of PCE to below the District's temporary operating goal of 35 ug/L. Normal fluctuation caused by water demand in the zone kept the PCE levels below 20 ug/L until the reservoir was taken out of service for sandblasting and recoating in December, 1980.

Reservoir V represented a different situation than occurred with the first two reservoirs. Whereas Reservoirs B and R had been in service for some time prior to the discovery of PCE, Reservoir V had just been coated. As shown in Figure 5, the first sample collected from Reservoir V indicated PCE levels approaching 300 ug/L. The District's immediate response was to drain and air-cure the reservoir for one month. As shown, the short air-cure even with forced air ventilation was ineffective in significantly reducing the PCE.

Under normal operating conditions, Reservoir V would have been drained a second time and air-cured for a longer period. However, it was necessary for the tank to remain at 50% capacity for fire protection purposes. Thus the reservoir was valved out, but remained half-full for about seven months. During that time PCE levels exceeded 900 ug/L. At the end of seven months, the reservoir was drained, cleaned and put into service.

Unlike Reservoirs B and R, which turned over very frequently on their own, the system water demand was not as high on Reservoir V. As a result, it was necessary to turn the reservoir over by partially draining and filling the tank at monthly intervals. This was the only way to assure that the PCE levels would remain at the operating goal of 35 ug/L. Although the PCE levels decreased with time, the tank was taken out of service in March, 1980 for sandblasting and recoating.

The fourth reservoir shown to contain PCE was Reservoir A. When this tank was first sampled for PCE, it had been in service for about one year. As shown in Figure 6, PCE levels were much higher in this reservoir than in Reservoirs B or R. One explanation for this was that Reservoir A stayed full much of the time and did not turn over. This is because it was constructed at an elevation several feet lower than the other tanks in the zone.

To dilute existing PCE levels and to induce reservoir turnover, the strategy for operating Reservoir A was to completely drain and fill the tank on a monthly basis. The effects of the drain and fill operation are shown in Figure 6. The practice was continued until the tank was taken out of service for sandblasting and recoating in February, 1980. Subsequent testing indicated no detectable testing PCE.

SOLVENT TESTS

Following the discovery of PCE in the four storage reservoirs, it became apparent that there was a need to evaluate coating materials for solvent leaching as well as for BGSP and taste and odor. Because of facilities limitations, solvent testing was limited to volatile organics that would show up during routine THM analyses. The following screening procedure was developed to identify coatings that contain halogenated organic solvents: Samples of the cured material were prepared on glass microscope slides and placed in a closed container for two weeks. The headspace gas in the container was then analyzed for halogenated organics using the THM procedure.

To more closely approximate field conditions a second procedure was developed. This consisted of exposing a cured coating sample to organic-free water for 2 weeks and analyzing the water for THMs and other purgeable, halogenated organics.

The information that can be obtained from these procedures is limited because the THM analysis is capable only of detecting a limited range of organic constituents. In addition, the testing is not quantitative because of many possible variations in coating thickness, surface to volume ratios, and curing time. Nevertheless, this screening approach is useful for detecting many purgeable, halogenated solvents. The test is valuable and would have predicted the presence of PCE in the coating originally applied to Reservoirs B, R, V and A.

MATERIAL SAFETY DATA SHEETS

Seeking the assistance of coating manufacturers in identifying other organics that may be leached into water, the District tried to obtain information about specific product formulations. Unfortunately, but understandably, the manufacturers were reluctant to disclose proprietary information. However, when letters asking the manufacturers to indicate whether or not their products contained any of EPA's 129 toxic priority pollutants were sent, most manufacturers were willing to comply. Manufacturers' certification regarding the presence of priority pollutants became one of the District's criteria for approving coating materials in 1979.

In 1982, another useful piece of information became available. As a result of the Hazardous Substances Information and Training Act of 1982, coating manufacturers were required to prepare material safety data sheets (MSDSs) for each of their products. Section II in an MSDS lists the solvents and other potentially hazardous substances present in the formulation. Although some manufacturers still refuse to list proprietary information on the MSDS, the primary solvents are usually listed. This represents much more information than was available previously.

CURRENT MATERIALS TESTING PROTOCOL

The District's materials testing program currently consists of the following activities:

1. Corrosion coupon test

2. BGSP test

3. Taste and odor test

4. Solvent test

5. Manufacturer's statement and MSDS

6. Follow-up organics monitoring (optional)

The expense of testing materials for water quality is justified only if a particular coating can first be demonstrated to be effective in preventing corrosion. Following corrosion coupon tests, materials are subjected to BGSP, taste and odor, and solvent tests. In addition, coating and lining manufacturers now are required to provide Material Safety Data Sheets on their products and respond to a letter requesting the disclosure of any ingredients present on EPA's toxic pollutant list.

If there is any indication that a particular pollutant may represent a problem, and there are no alternative materials that may be selected for a particular job, follow-up monitoring of organic constituents in the stored water may be warranted. Such monitoring was undertaken following the installation of a new hypalon liner in a 5 MG concrete reservoir in the Spring of 1983.

HYPALON LINERS

Early problems detected with the installation of hypalon liners involved the use of a solvent containing trichloroethylene (TCE). Residual TCE from seaming procedures did not dissipate readily. High levels of the contaminant were detected in a number of drinking water reservoirs lined with the material.

Coinciding with the issuance of an EPA Health Advisory for TCE, the solvent was removed from adhesives used in the construction of hypalon liners. TCE was replaced with solvents considered to be less hazardous. The manufacturers of these materials labeled them "potable grade" to indicate the absence of solvents considered by EPA to be particularly hazardous. Xylene is the solvent which replaced TCE in most hypalon applications. EPA's Suggested No Adverse Response Level (SNARL) for chronic exposure to xylene and TCE are 620 ug/L and 75 ug/L, respectively.

When it was decided that a liner was needed to stop the leakage occurring in one of the District's 5 MG concrete reservoirs, a hypalon liner using "potable grade" adhesives was specified. When installing a liner, as opposed to a coating or paint, there usually is a greater variety of components to consider as potential contaminants. With the Diablo job, two different adhesives were used, one containing hexane and the other containing xylenes. In addition, industrial grade xylene was applied directly to seaming surfaces of the hypalon sheets to assure a clean bonding between sheets.

Most of the solvent used for lining installations is associated with on-site seaming. Fortunately, contractors installing the lining try to minimize on-site seaming because it is less expensive to do factory seaming and work with a minimum number of lining pieces on-site. Factory seaming is aided by the application of heat and does not necessitate as much solvent. On-site seaming requires that overlapping pieces of hypalon are wiped clean with xylene and joined using an adhesive compound containing more solvent. The curing time recommended by the manufacturer of the Diablo Reservoir hypalon sheet and adhesive materials was three days. This recommendation was based on the time required for maximum seam strength (or 90% solvent dissipation).

When the District's Diablo Reservoir was relined, the inside of the tank still had a very strong solvent odor after the three-day curing period. To determine the quantities of residual solvent or other organic contaminants that might be present in a newly lined reservoir, the tank was filled after the minimum curing time of three days. Samples for taste and odor, acid and base neutral extractables, pesticides and chlorinated hydrocarbons, and purgeable volatile organics analyses were collected after the reservoir had stood full for two weeks. This was intended to represent a worse case situation in that newly lined or coated reservoirs usually are filled and drained at least once before being returned to service.

The results of initial organics monitoring are shown in Table 1. This table shows all the quantifiable volatile organics detected in the reservoir sample and a control sample collected from a nearby distribution system sample tap. As expected, the trihalomethanes (chloroform and bromodichloromethane) were present in both samples. Also as expected, no pesticides, PCBs or acid or base neutral extractables were detected. Purgeable volatile organics other than trihalomethanes were detected only in the reservoir and not in the control sample.

It was anticipated that xylenes would be present in the greatest quantities because Material Safety Data Sheets indicated that xylene was the primary solvent in the potable grade adhesives. Ethylbenzene was not expected. However, ethylbenzene is a contaminant of commercial grade xylene and probably was present for this reason. The presence of other organic compounds shown in Table 1 could not be explained readily.

Table 1 also indicates available information on the taste and odor thresholds of detected organic compounds. A taste and odor sample collected during the first filling of Diablo Reservoir indicated a very strong solvent odor. The table indicates that ethylbenzene was present at levels which produce detectable odors.

Information was not available on the odor threshold for xylene. However, the odor detected in Diablo Reservoir was much like that of xylene, so it was assumed that the level of xylene detected (66 ug/L) was great enough to cause the strong solvent odor. Subsequent testing by Metropolitan Water District of Southern California indicates that xylene levels as low as 20 ug/L result in detectable solvent odors[6].

In an effort to eliminate the taste and odor, the reservoir was drained and filled. This failed to eliminate the solvent odor and it was decided to provide extended air-curing with forced ventilation. The reservoir was ventilated for about three weeks before filling for a third time. By this time, most of the odor inside the tank had dissipated. The tank was put in service and the surface elevation was fluctuated to prevent accumulation of any residual solvents. Approximately 25% of the tank's capacity was replaced every 8 hours during the first week the reservoir was returned to service. Not a single taste or odor complaint was received.

As a follow up to the initial organics monitoring, Diablo Reservoir was sampled for purgeable volatiles twice more, once after two months and again after six months in service. The results are shown in Table 2. Also shown are available health related criteria or standards for the compounds detected. If there is a Maximum Contaminant Level (MCL) or California Department of Health Services action level, these are included. Otherwise, EPA (SNARLS) or water quality criteria for the protection of human health are indicated. None of the compounds detected in Diablo Reservoir were present at levels exceeding any present health advisory levels.

As expected, with increased time in service there were decreases in the predominant contaminants xylene and ethylbenzene. Sampling is being conducted presently to evaluate the levels of organic compounds remaining after one year in service.

SUMMARY

Some coating and lining materials have been shown to be a source of water quality problems in finished water reservoirs. The East Bay Municipal Utility District has encountered materials which enhance the growth of bacteria, contribute tastes and odors, and/or leach organic contaminants into finished water.

To avoid water quality problems, the District has developed a materials testing protocol for evaluating coatings and linings to be used in contact with potable water. The evaluation process includes testing for bacterial growth support potential (BGSP), taste and odor, and purgeable, halogenated solvents that can be detected during trihalomethane (THM) analyses. More sophisticated organics analyses may be required to detect the variety of compounds utilized in the manufacture of coating and lining materials.

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7. Alexander, H. C., W. M. McCarty, E. A. Bartlett, and A. N. Syvervd. 1982, Aqueous Odor and Taste Threshold Values of Industrial Chemicals. Journal of the American Water Works Association 74, 595-599.

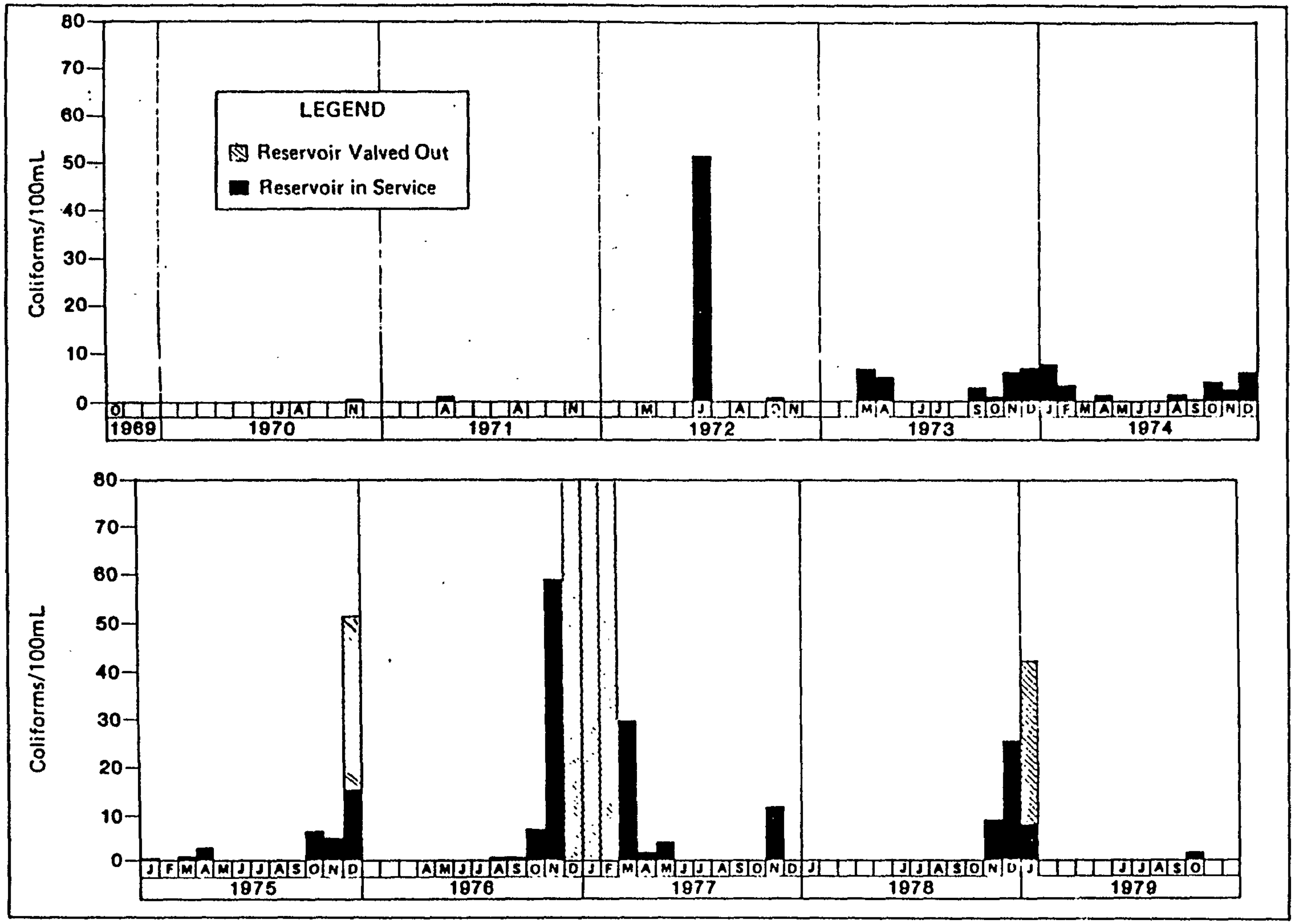

Figure 1
Average Coliform Counts in Bayview No. 2 Reservoir
1969 – 1979

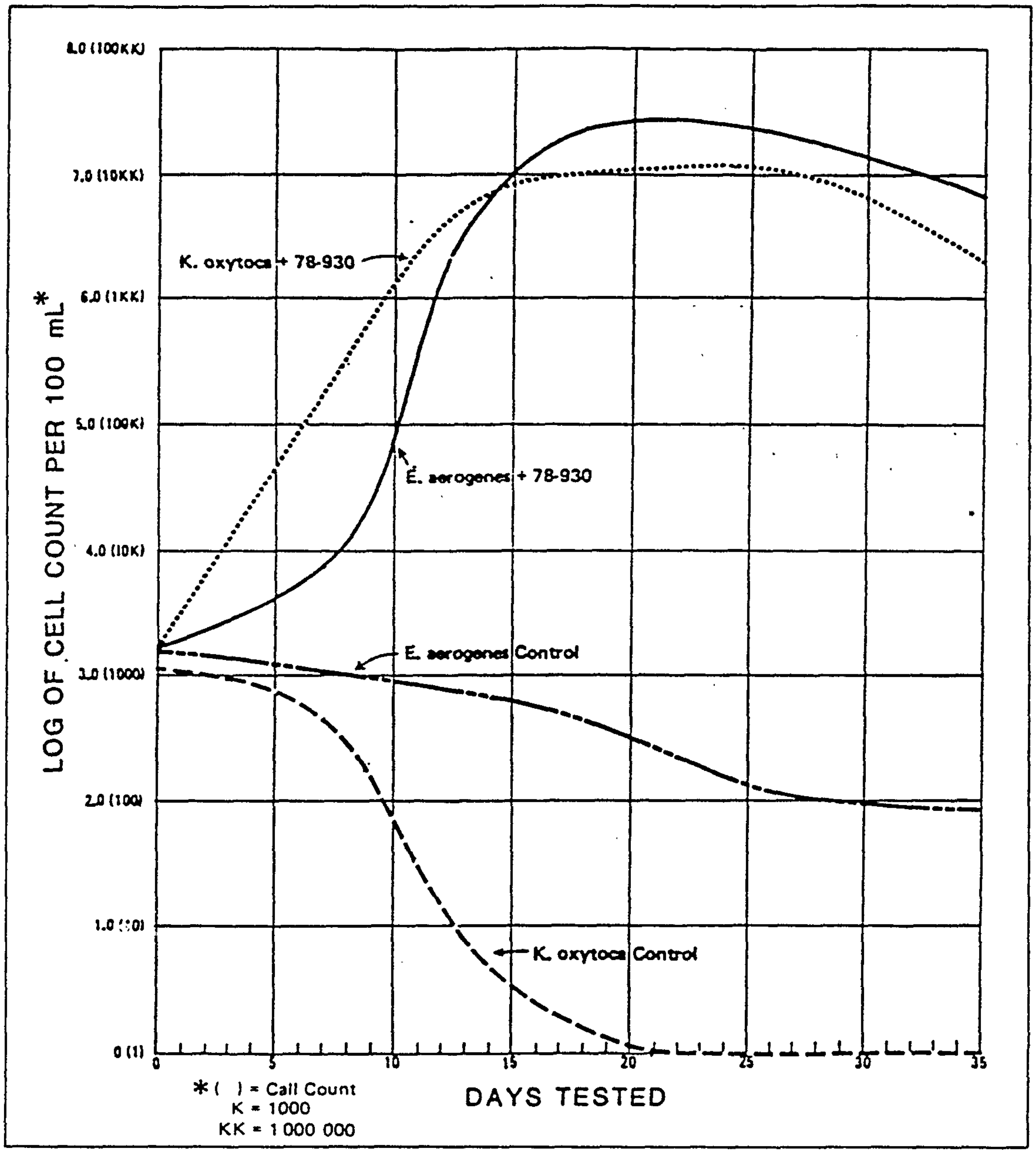

Figure 2
Typical Growth Curve from
Bacterial Growth Support Potential Test

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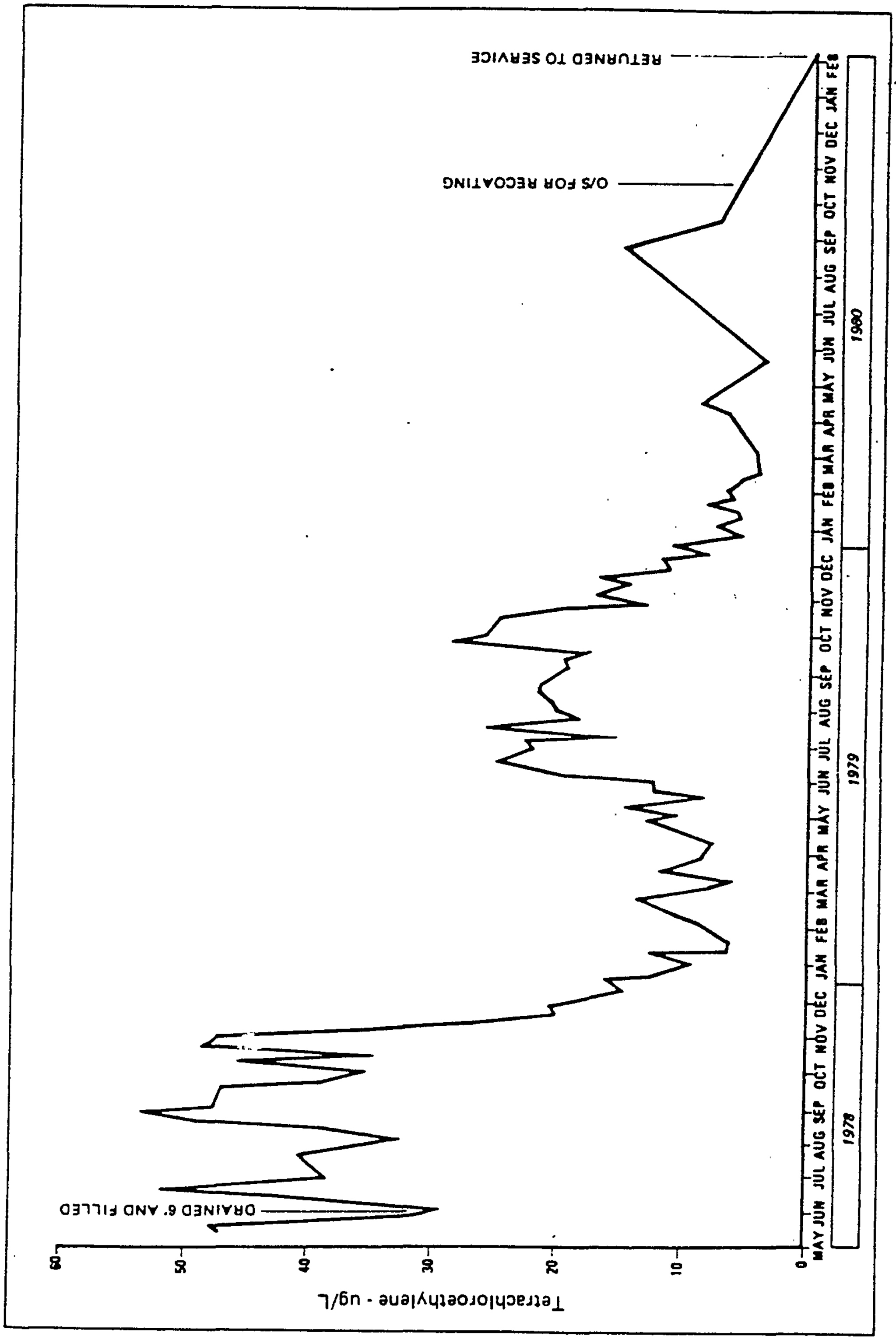

Figure 3
Tetrachloroethylene in Reservoir B

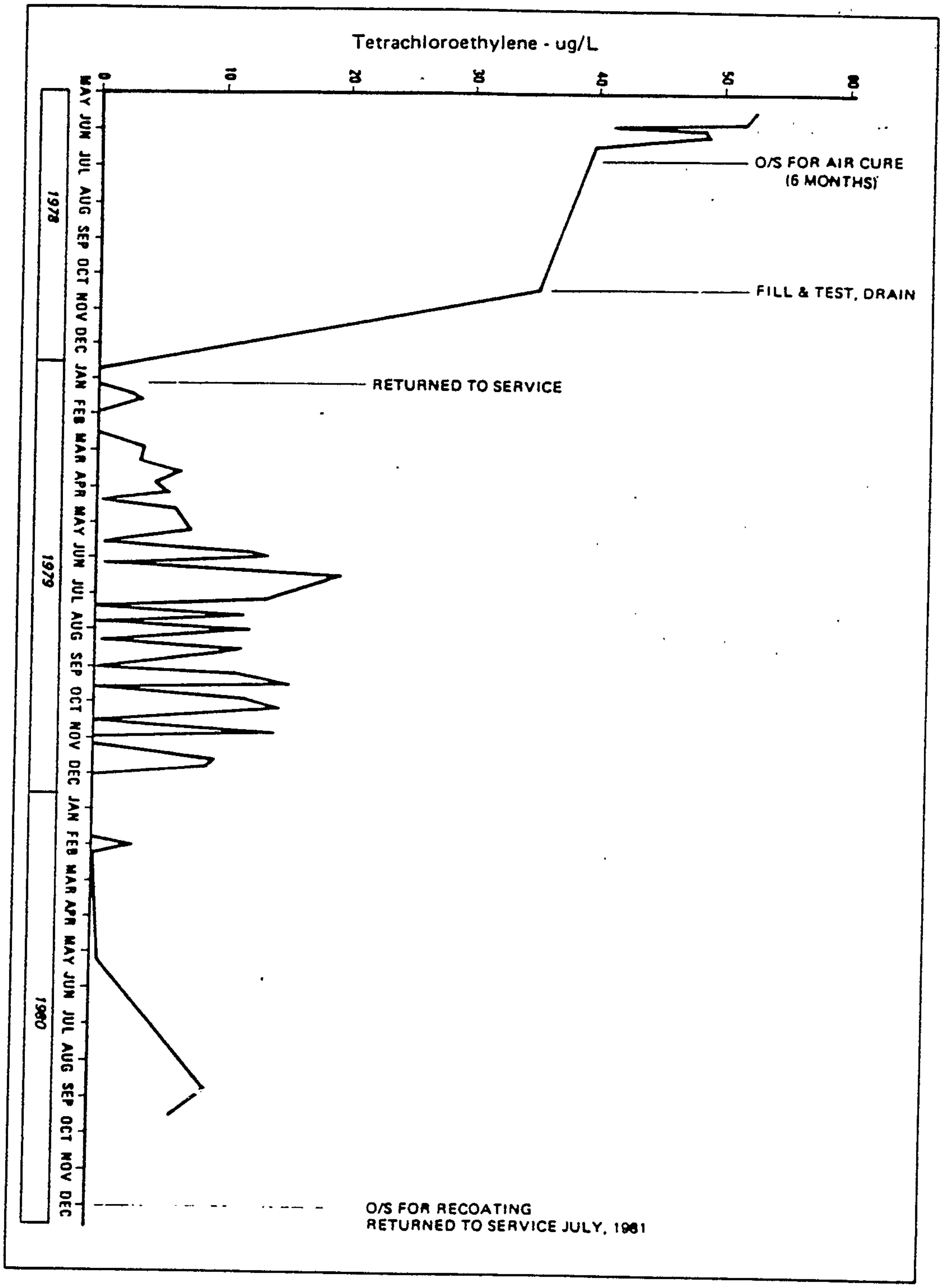

Figure 4
Tetrachloroethylene in Reservoir R

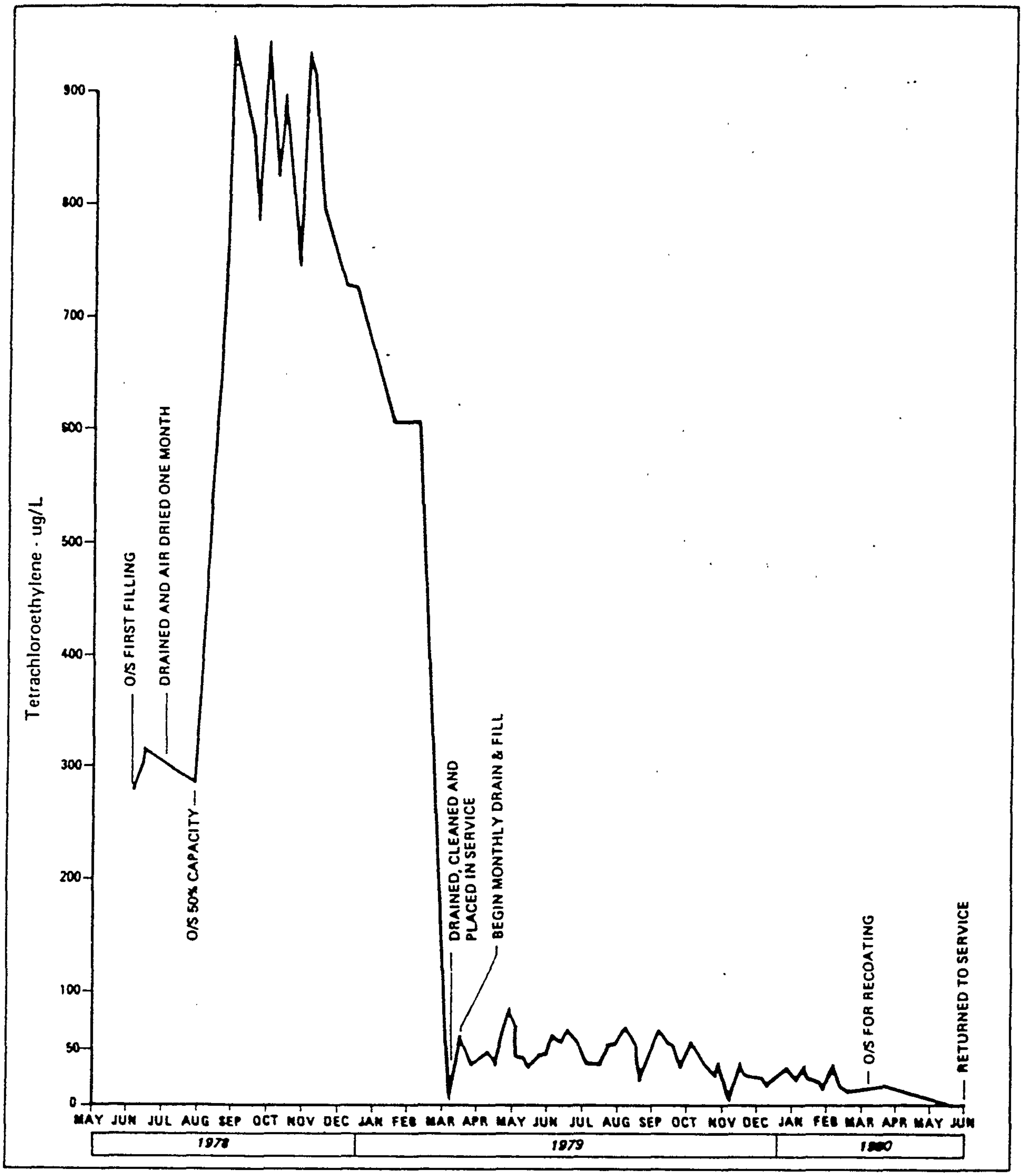

Figure 5
Tetrachloroethylene in Reservoir V

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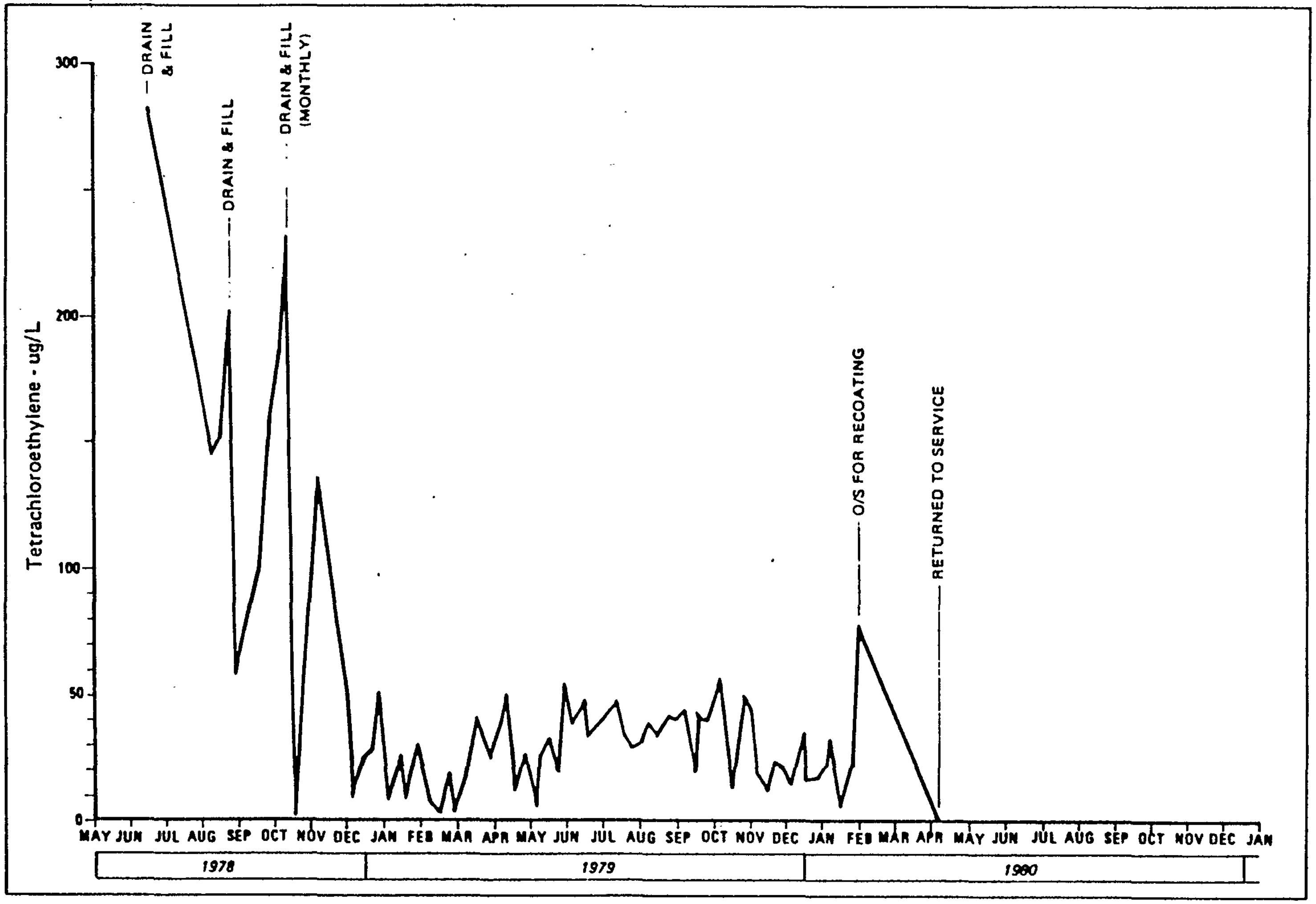

Figure 6
Tetrachloroethylene in Reservoir A

TABLE 1

DIABLO RESERVOIR – INITIAL ORGANICS SAMPLING FOLLOWING INSTALLATION OF HYPALON LINING

COMPOUND	CONCENTRATION (ug/L) RESERVOIR	CONTROL	TASTE THRESHOLD (ug/L)[7]	ODOR THRESHOLD (ug/L)[7]
Chloroform	59	50	12 000	1000
Bromodichloromethane	2.0	1.9		
Dichloromethane	1.7	ND		
Trichlorofluoromethane	0.4	ND		
Carbon Tetrachloride	1.2	ND	3 600	1000
Toluene	2.1	ND	140	24
Ethylbenzene	21	ND	72	2.4
m, p-xylene	56	ND		
o-xylene	10	ND		

ND – Not Detected

[7] From Alexander, H. C. et al. (1982)

TABLE 2

DIABLO RESERVOIR – PURGEABLE VOLATILE ORGANICS MONITORING FOLLOWING INSTALLATION OF HYPALON LINING

COMPOUND	CONCENTRATION (ug/L)			REFERENCE CONCENTRATION
	FIRST FILLING	TWO MONTHS	SIX MONTHS	
Chloroform	59	50	30	100 (TTHM)*
Bromodichloromethane	2.0	1.0	ND	100 (TTHM)
Dichloromethane	1.7	ND	ND	–
Trichlorofluoromethane	0.4	1.0	ND	–
Carbon Tetrachloride	1.2	ND	0.3	5**
Toluene	2.1	ND	ND	100**
Ethylbenzene	21	2.9	0.4	1400†
m, p-xylene	56	12	1.4	620**
o-xylene	10	1.6	0.3	620**

ND – Not Detected
* – National Interim Primary Drinking Water Regulation maximum contaminant level
** – California Department of Health Services action level
† – EPA ambient water quality criterion for protection of human health

Exhibit 53

Library – Tank Coating

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY

GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF HEALTH SERVICES

714/744 P STREET
SACRAMENTO, CA 95814

Memorandum

To: All Large Public Water Systems

Date: December 30, 1985

From: Sanitary Engineering Branch

Subject: Tank Coatings

In 1982, we alerted you of our concerns regarding possible organic chemical contamination resulting from improper selection, application, and use of coatings for water storage facilities. At that time we suggested special precautions to be taken to minimize the hazards of this problem. Our experience has revealed that in many cases, organic chemical contaminants (i.e. TCE, PCE) leached from the coating material, exceed State action levels. When this occurs, we will not allow the storage facility to be placed into service until the contaminated levels are reduced to below the action level.

To verify the concentration of any organic chemical contaminant, the following actions shall be required whenever a storage facility is coated:

1. Following a five-day soaking period, the water in the tank shall be sampled to determine the presence of any leached organic chemicals. Samples of the water shall be analyzed by a laboratory certified by the State Department of Health Services for the presence of any volatile organics.

2. Using State action levels as guidelines, utilities shall determine that the water is of acceptable quality and place the tank in service as appropriate. Positive samples above action levels shall be immediately reported to the State Department of Health Services. If any VOC exceeds the State action level, the tank should remain out of service until corrective action is taken and resamples indicate that VOC levels are below action levels.

3. A written report shall be submitted to the State Department of Health Services of all test results and the date the tank was placed in service.

The above procedure for notification of the State Department of Health Services will enable utilities to perform the necessary water quality testing without causing delays in placing newly coated tanks in service.

Since it is difficult to correct coating problems after they are discovered, considerable care should be exercised in the selection and application of coating materials.

DEFENDANTS' EXHIBIT 528 FOR ID
BRYAN LUI, CSR NO. 11223
DATE: 6-3-99
WITNESS: GEDNEY

Some of the important precautions to be considered are indicated below for your guidance:

1. Whenever a tank is proposed to be coated, you should contact our District office regarding the proposal. Although we have no authority to approve proprietary products, we may be able to advise you of additional precautions to be taken for certain coatings. This could help you avoid some problems later.

2. Only experienced and competent applicators should be employed to apply the coatings. The coating manufacturer's application recommendations must be closely followed, especially the curing ventilation and curing time. Whenever forced air ventilation is recommended, it should be used for proper curing. Air should be drawn out from the lowest part of the tank since the volatile organic vapors are heavier than air. If there is any doubt about the adequency of the curing conditions, additional curing time with continued forced air ventilation should be provided. Experience has shown that the amount of curing time suggested by the manufacturer is adequate only if temperature and humidity conditions are near ideal. Following the curing period, the tank should be washed and disinfected in accordance with AWWA D105-80 before filling.

Since we began sampling of water for organic chemical contaminants, we have found several previously coated tanks to continue to leach significant amounts of solvent even several years after application of the coating. We, therefore, advise that you sample some of your previously coated tanks to determine whether a problem exists, especially if there have been taste and odor complaints. This coating problem may also affect coated pressure tanks although the problem may be minimal due to the large volume of water passing through the tank.

If this Branch can be of any assistance, please do not hesitate to contact one of our District offices.

Sincerley,

Peter A. Rogers

Peter A. Rogers, Chief
Sanitary Engineering Branch

Exhibit 54

GEORGE DEUKMEJIAN, Governor

DEPARTMENT OF HEALTH SE[illegible]ES
714/744 P STREET
SACRAMENTO, CA 95814
(916) 323-1382

August 14, 1986

City of San Bernardino
300 North D Street
San Bernardino, CA 92401

PERMIT AMENDMENT

Application from the City of San Bernardino Municipal Water Department dated August 6, 1985 for an amended permit to construct and operate two counter-current, packed tower, air stripping units to remove volatile organic chemicals from the water produced by four existing water supply wells (Newmark Wells 1,2,3, and 4), has been considered by the State Department of Health Services. The application was made in accordance with Section 4019 of the Health and Safety Code. Enclosed is a copy of the engineering report dated July 21, 1986, prepared by the Sanitary Engineering Branch regarding your application.

It is the Finding of the State Department of Health Services that Section 4010 to 4039.5, inclusive, of the California Health and Safety Code can be met by the City of San Bernardino water system using the proposed new facilities. This finding is based on the cited report. An amended domestic water supply permit is hereby granted to the City of San Bernardino to construct and operate two counter-current, packed tower, air stripping units to remove volatile organic chemicals from the water produced by Newmark Wells 1,2,3 and 4, and deliver it to the domestic water consumers in the City of San Bernardino subject to the following provisions:

1. Plans and specifications for the treatment facilities to be constructed at the Newmark reservoir site shall be submitted for review and approval to the San Bernardino office of the Department of Health Services, Sanitary Engineering Branch (DHS-SEB) prior to construction.

2. After completion of construction and prior to distribution of water from the Newmark reservoirs, the facilities must be operated for an initial period during which the adequacy and reliability of treatment shall be assessed. A written report evaluation monitoring results and operation during the initial operation period shall be submitted to DHS-SEB for review and approval before water from the facility is distributed for domestic purposes.

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3. All water delivered from the Newmark reservoirs for domestic purposes must meet all Maximum Contaminant Levels and Action Levels established by the State Department of Health Services.

4. All water entering the system from the Newmark reservoirs shall be continuously and reliably chlorinated.

5. All persons operating any City water treatment facility must be certified by the California Department of Health Services in accordance with Title 17, Part I, Chapter 5, Subchapter I of the California Administrative Code.

6. Prior to changing the method of treatment or location of treatment facilities for the Newmark wells, the City shall submit the proposed changes in writing to DSH-SEB for review and approval. If major changes are to be made, the City must apply for and receive an amended permit from DHS-SEB.

7. Samples of the raw and treated water shall be collected as required by DHS-SEB and analyzed for purgeable halocarbons, purgeable aromatics, bacteriological quality and appropriate chemical constituents by an approved laboratory. Analytical results must be submitted in the format and at the frequency required by DHS-SEB.

8. Daily operational records including, as a minimum, flow rates, total volume treated, air-to-water ratios, changes and unusual occurrences shall be maintained and a monthly summary shall be submitted by the 10th of the following month to DHS-SEB.

9. As-built plans for the treatment facilities installed at the Newmark reservoir shall be submitted to DHS-SEB within six months of completion of construction.

This permit amends the existing permit granted to this system on October 7, 1964 and as amended on April 23, 1982 and July 11, 1986.

Peter A. Rogers, Chief
Sanitary Engineering Branch

Enclosure

cc: San Bernardino County
Department of Environmental Health Services

City of San Bernardino
Att: Joe Stejskal

DHS, Toxics Division
107 S. Broadway
Los Angeles, CA 90012

CRWQCB, Santa Ana Region
6809 Indiana Ave., Suite 200
Santa Ana, CA 92506

bcc: SEB - San Bernardino -
Diana Barich
Chet Anderson

DEPARTMENT OF HEALTH SERVICES
SANITARY ENGINEERING BRANCH
606 EAST MILL STREET, SUITE 1011
SAN BERNARDINO, CA 92408
(714) 383-4328

Engineering Report
For Consideration of the Permit Application from
The City of San Bernardino Municipal Water Department
Serving the City of San Bernardino, San Bernardino County
July 21, 1986

Sanitary Engineering Branch
State Department of Health Services
W. C. Gedney, Project Engineer

By application dated August 6, 1985, the City of San Bernardino Municipal Water Department applied for a permit to construct and operate two counter-current, packed tower, air stripping units to remove volatile organic chemicals from the water produced by the City's four existing Newmark wells (Numbers 1, 2, 3 and 4) located in North San Bernardino. Up to 8.6 million gallons of water per day will be treated at the site and distributed for domestic purposes. The City of San Bernardino water system operates under a domestic water supply permit granted by this Department on October 7, 1964 and amended on April 23, 1982 and July 11, 1986.

The Newmark Wells, which are located in a residential area of North San Bernardino, were first found to be contaminated with volatile organic chemicals, primarily Trichloroethene (TCE) and Perchloroethene (PCE) in July, 1980. Initially, concentrations of TCE up to 4.2 parts per billion (ppb) and of PCE up to 15.0 ppb were found. Current levels of TCE range from 8.0 ppb to 31.4 ppb. PCE ranges from 23.0 ppb to 165.0 ppb. Attached is a summary of the TCE and PCE concentrations from 1980 to the present. All four wells pump directly into the adjacent 20 million gallon Newmark reservoir complex.

In November 1984, the City had their consulting engineers initiate an evaluation of possible treatment options and devise a protocol for performing a pilot-scale study. The consultants determined that air stripping of the volatile organic chemicals using counter-current, packed towers was the most reliable and cost effective treatment technology available for this situation. The City constructed a 20 foot high, 3 foot diameter packed tower pilot plant and initiated pilot studies. During the pilot plant program, liquid loading rates were varied with respect to several air-to-water ratios and two types of packing media (Trico and Glitch). Based on the evaluation of the pilot study findings, the City determined that a full scale treatment facility could effectively and reliably remove volatile organic chemicals from the water produced by all four of the Newmark Wells.

Two separate treatment units will be constructed. Each unit will be composed of a 44 foot high by 12 foot diameter stripping tower. Each tower will treat up to 3000 gallons per minute and will have a packing material bed depth of 21.5 feet. A 30 horsepower, 20,000 cubic feet per minute blower will provide for an air-to-water ratio of 50 to 1. It is anticipated that the treatment units will remove in excess of 99.9% of the volatile organics present. The TCE and PCE concentration in the effluent from the treatment units should be less than 1.0 ppb. As an additional safety factor the treated water will be reliably blended in the Newmark reservoirs with water from uncontaminated sources.

The City was required to obtain approval of its air stripping facilities from the South Coast Air Quality Management District (SCAQMD). The SCAQMD has issued construction permits for each of the two proposed aeration towers (copies attached). The permits limit the maximum concentrations of TCE and PCE in the well water to be treated to 40 ppb and 200 ppb respectively.

SEB has thoroughly reviewed the pilot plant studies and the City's proposed treatment criteria. Based on that review and the findings of the pilot plant test program, the proposed treatment facilities can effectively and reliably remove volatile organic chemicals from the Newmark well (Numbers 1, 2, 3 and 4).

Issuance of an amended domestic water supply permit by the State Department of Health Services to the City of San Bernardino Municipal Water Department for the proposed treatment facilities is recommended, subject to the following special provisions:

1. Plans and specifications for the treatment facilities to be constructed at the Newmark reservoir site shall be submitted for review and approval to the San Bernardino office of the Department of Health Services, Sanitary Engineering Branch (DHS-SEB) prior to construction.

2. After completion of construction and prior to distribution of water from the Newmark reservoirs, the facilities must be operated for an initial period during which the adequacy and reliability of treatment shall be assessed. A written report evaluating monitoring results and operation during the initial operating period shall be submitted to DHS-SEB for review and approval before water from the facility is distributed for domestic purposes.

3. All water delivered from the Newmark reservoirs for domestic purposes must meet all Maximum Contaminant Levels and Action Levels established by the State

Department of Health Services.

4. All water entering the system from the Newmark reservoirs shall be continuously and reliably chlorinated.

5. All persons operating any City water treatment facility must be certified by the California Department of Health Services in accordance with Title 17, Part I, Chapter 5, Subchapter 1 of the California Administrative Code.

6. Prior to changing the method of treatment or location of treatment facilities for the Newmark wells, the City shall submit the proposed changes in writing to DHS-SEB for review and approval. If major changes are to be made, the City must apply for and receive an amended permit from DHS-SEB.

7. Samples of the raw and treated water shall be collected as required by DHS-SEB and analyzed for purgeable halocarbons, purgeable aromatics, bacteriological quality and appropriate chemical constituents by an approved laboratory. Analytical results must be submitted in the format and at the frequency required by DHS-SEB.

8. Daily operational records including, as a minimum, flow rates, total volume treated, air-to-water ratios, changes and unusual occurrences shall be maintained and a monthly summary shall be submitted by the 10th of the following month to DHS-SEB.

9. As-built plans for the treatment facilities installed at the Newmark reservoirs shall be submitted to DHS-SEB within six months of completion of construction.

Attachment Number 1
To City of San Bernardino Amended Permit
Dated July 11, 1986

Summary of Results of TCE/PCE Samples from the City of San Bernardino
Newmark Wells
All Analyses Conducted by Approved Laboratories
All Values Are In Parts Per Billion (ppb)

Well Number	No. 1		No. 2		No. 3		No. 4	
	TCE	PCE	TCE	PCE	TCE	PCE	TCE	PCE
Date Sampled								
7/29-30/80			0.26	0.51	4.2	1.5	<.01	.03
8/6/80	1.3	9.4			5.0	19		
8/20/80	1.0	8.9			4.5	21	<.05	<.05
8/27/80	1.0	9.0			3.8	20		
9/10/80			0.54	0.80	4.6	18	<.1	<.1
9/26/80					3.9	18.8	<.25	<.25
8/14-21/81	3.0	15			3.9	21		
9/18/81	2.1	16			4.3	21		
11/24/81			0.60	1.7	5.3	29		
9/28/82	4.2	31	<.1	<.1	7.2	41	<.1	<.1
1/13/83	2.7	13.7	<.2	1.1	10	51	0.88	5.1
8/16/83	5.7	42	0.29	2.4	12	73	<.1	<.1
11/7/83	3.3	22.4	<.2	<.2			<.2	<.2
11/13-18/84	<.2	4.2	<.2	<.2			<.2	<.2
2/14/84	2.0	18			13	72	<.2	<.2
7/23/84	1.7	7.7	<1.0	<1.0	6.6	37	1.6	6.9
10/8/84	3.9	24	1.1	7.4	14	68	4.9	28
1/22/85	7.6	44	0.5	2.0	16	84	10	52
1/25/85					17	91		
2/12/85	11	46						
2/28/85	6.5	144.9			15.6	123.4		
5/20/85			2.6	14.1				
5/28/85			<.2	<.1				
5/30/85	6.2	61.8	<.2	6.5	1.6	64.2	11.0	64.1
6/3/85			1.7	14.2				
6/10/85			.4	11.9				
6/17/85			2.2	8.5				
7/8/85			1.8	11.5				
7/15/85			2.4	15.7				
7/22/85			0.4	3.0				
8/6/85	13.9	55.3	1.9	17.8			9.4	116
8/12/85			2.5	15.7				
10/14/85	18.4	48.4	4.5	19.5	17.5	48.0	23.0	50.3
4/11/85	18.8	145	4.0	36.0	15.7	165	21.8	136
5/14/86	15.4						28.4	131.5
6/11-13/86	17.2	88.1	8.0	23.0	20.4	102	31.4	114.9

CITY 05-0220

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(Domestic Water Supplies, Form A1, Municipal Corporation or Civil Subdivision)

STATE OF CALIFORNIA

DEPARTMENT OF HEALTH

Application from City of San Bernardino Municipal Water Department
(Name of municipality or civil subdivision)

organized under City Charter - 1904
(State whether special charter or under general law, giving class and date of incorporation)

To the State Department of Health
2151 Berkeley Way
Berkeley, California 94704

Pursuant and subject to all of the terms, conditions and provisions of Division 5, Part 1, Chapter 7, Sections 4010 to 4035 of the California Health and Safety Code and all amendments thereto, relating to domestic water supplies, application is hereby made to said State Department of Health for a permit to

(SEE ATTACHED SHEET)

Applicant must state specifically what is being applied for—whether to construct new works, to use existing works, to make alterations or additions in works or sources and state nature of improvement in works. Enumerate definitely source or sources of supply, kind of works used or considered (if known) and specify the locality to be served. Additional sheets may be attached.

Dated August 6, 19 85.

[AFFIX OFFICIAL SEAL HERE]

CITY OF SAN BERNARDINO MUNICIPAL WATER DEPARTME
(Name of municipality or civil subdivision, in full)

By [signature]
(Signature of chief executive officer with official title and post office address)

Herbert B. Wessel

P. O. Box 710
San Bernardino, CA 92402

Attest [signature]
(Signature of clerk or corresponding official with title and post office address)

P.O. BOX 710, San Bernardino, CA 92402

CITY 05-0221

NOTES

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The Municipal Water Department proposes to install, test and operate two (2) 12' diameter, 38' high counter-current packed tower air stripping units to remove volatile organic compounds (TCE/PCE) from a domestic drinking water aquifer. The equipment shall be located at the 48th Street and Reservoir Drive reservoir and treat four (4) domestic water wells - 6000 8000 gpm. A gas chlorinator will be installed at the effluent of the stripping tower.

The unit will contain automatic shut-down and remote alarm for power failure, equipment malfunction, and high or low chlorine levels. As an additional safety feature, the final effluent from the air stripping unit will be blended to a minimum ratio of 50-50, with higher elevation uncontaminated well water at the point of discharge into the Newmark 22 MG reservoir.

The general location being served is the upper Central San Bernardino City Limits. Approximately 20,000 services will be served.

Domestic Water Supplies, Form A2, Municipal Corporation or Civil Subdivision)

STATE OF CALIFORNIA

DEPARTMENT OF HEALTH

Certified Copy of Resolution

(To accompany application on Form A1)

"Resolved by the Board of Water Commissioners
(City council, board of trustees or other governing body)

of the City of San Bernardino Municipal Water Department
(City, town or county, etc.)

that pursuant and subject to all of the terms, conditions and provisions of Division 5, Part 1, Chapter 7, Sections 4010 to 4035 of the California Health and Safety Code and all amendments thereto, relating to domestic water supplies, application by this City (City, town or county, etc.) be made to the State Department of Health, for a permit to

(SEE ATTACHED SHEET)

Applicant must state specifically what is being applied for—whether to construct new works, to use existing works, to make alterations or additions in works or sources and state nature of improvement in works. Enumerate definitely source or sources of supply, kind of works used or considered (if known) and specify the locality to be served. Additional sheets may be attached.

that the General Manager (Title of chief executive officer) of said City of San Bernardino Municipal Water D (City council, board of trustees or other governing body)

be and he is hereby authorized and directed to cause the necessary data to be prepared, and investigations to be made, and in the name of said City (City, town or county, etc.) to sign and file such application with the said State Department of Health.

Passed and adopted at a regular meeting of the Board of Water Commissioners
(Governing body)

of the City of San Bernardino (City, town or county, etc.) on the 6th day of August, 1955.

CITY 05-0223

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[signature]

Affix Official Seal

Exhibit 55

INVESTIGATION OF SOURCES OF TCE AND PCE CONTAMINATION IN THE BUNKER HILL GROUND WATER BASIN

FINAL REPORT

Submitted to:

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SANTA ANA REGION
Riverside, California

August 1986

By:

URS Corporation
412 W. Hospitality Lane, San Bernardino, CA 92408
(714) 381-4566

In Association With:

ERM-West
Walnut Creek, CA

DEFENDANTS' EXHIBIT 554 FOR ID
BRYAN LUI, CSR NO. 11223
DATE: 6-10-99
WITNESS: STETSKAL, V.II

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CITY00140

URS
AN INTERNATIONAL PROFESSIONAL SERVICES ORGANIZATION

URS COMPANY
412 WEST HOSPITALITY LANE, SUITE 208
SAN BERNARDINO, CALIFORNIA 92408
TEL: (714) 381-4566

SEATTLE
LAS VEGAS
ANCHORAGE
JUNEAU
PORTLAND
SAN FRANCISCO
DENVER
DALLAS
KANSAS CITY
NEW ORLEANS
NEW YORK
WASHINGTON, D.C.
SAN MATEO
LONDON

August 8, 1986

State Water Resources Control Board
Regional Water Quality Control Board
Santa Ana Region
6809 Indiana Avenue, Suite 200
Riverside, California 92506

Attention: Dixie B. Lass, Contract Manager

Ladies and Gentlemen:

SUBJECT: Final Report, INVESTIGATION OF SOURCES OF TCE AND PCE CONTAMINATION IN THE BUNKER HILL GROUND WATER BASIN

The following report is being submitted to you today in 25 copies as the final submittal under the subject contract (Standard Agreement No. 5-099-180-2 between URS and the California General Services Administration).

I would like to acknowledge the assistance of our subcontractors, ERM-West (hydrogeology), J.H. Kleinfelder & Associates (drilling), James M. Montgomery (analytical laboratory), and Tracer Research Corporation (soil pore gas sampling) -- each of whom added special expertise to the discovery of a number of potential sources of TCE and PCE contamination.

Moreover, I would like to acknowledge the assistance of a Technical Advisory Committee, organized and chaired by your Contract Manager, Dixie Lass. Committee members' review comments on various task reports and draft materials were invaluable.

Quite naturally, despite the assistance we received, URS led the work; and we accept responsibility for the report, which culminates this interesting and, we believe, useful investigation. Thank you for the opportunity to study, understand better, and explain to the public the condition of our local water resource.

Respectfully submitted,

M B Sonnen

Michael B. Sonnen, Ph.D., P.E.
Project Manager

MBS:cmc

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Chapter 1.

INTRODUCTION

BACKGROUND

Several municipal water supply wells in the northwestern region of the City of San Bernardino, California have been closed during the past 5 years as a result of contamination by organic chemical solvents. Specifically, 14 wells have been closed because concentrations of trichloroethylene (TCE) or tetrachloroethylene (also known as perchloroethylene or PCE) have reached levels in these wells that exceed State Department of Health Services action levels for public water supplies. Exceeding State standards requires that the well owner take one of several actions to remedy the situation.

The immediate responses of local water suppliers have been either to close the contaminated wells and serve their customers from other existing sources, to drill new wells, or to undertake plans for rehabilitating the contaminated wells. It has not been the practice of the affected well owners to determine the source of contamination or to identify the party or parties responsible for the TCE or PCE discharges.

Because contamination exists, however, and because the water supplies of at least two agencies have been adversely affected and other wells are threatened, and because still more numerous service-area water users could be put at risk, the State Water Resources Control Board, (through the Regional Water Quality Control Board for the Santa Ana Region) initiated an investigation to seek the original source or sources of damaging TCE and PCE pollution.

On November 22, 1985, a contract was approved (Standard Agreement No. 5-099-180-0) by the California Department of General Services between the State Water Resources Control Board and URS Corporation, under which URS was to provide services for an investigation and necessary field testing to narrow as far as possible the potential sources of contamination. A final amended contract (Standard Agreement No. 5-099-180-2) was approved by the Department of General Services on July 7, 1986.

This final report presents the results of the URS study effort.

STUDY OBJECTIVES

The singular objective of this study was to identify and investigate sources of TCE and PCE contamination in the Bunker Hill Groundwater Subbasin in the San Bernardino area.

Figure 1 shows the relationship of the study area to the Bunker Hill subbasin and to the Santa Ana River Basin. Figure 2 shows the study area in the northwest portion of the City of San Bernardino and the locations of the 14 wells that have been closed by TCE and PCE contamination.

The investigation has been performed in a series of three tasks, each with its own subobjectives. These are summarized below.

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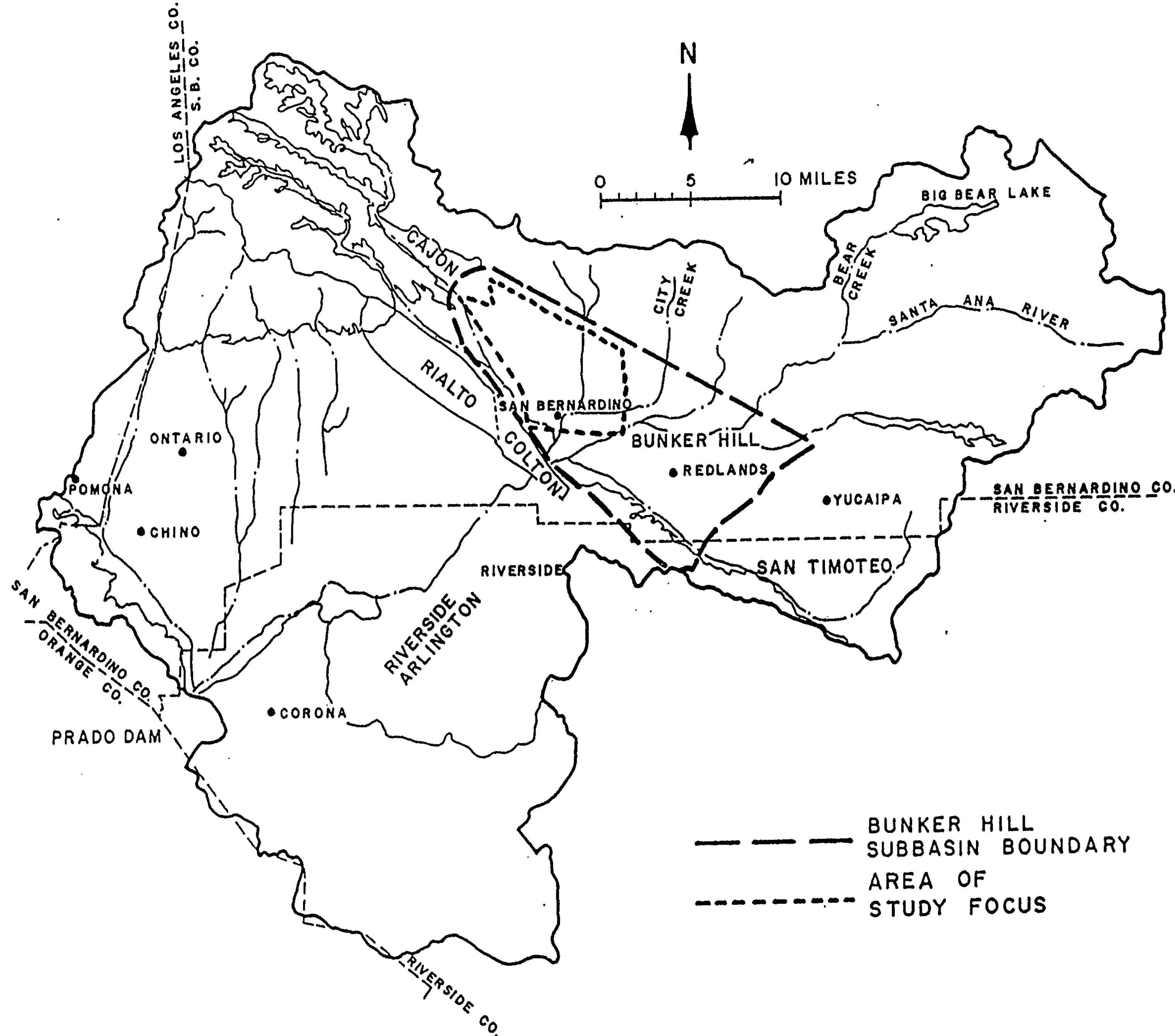
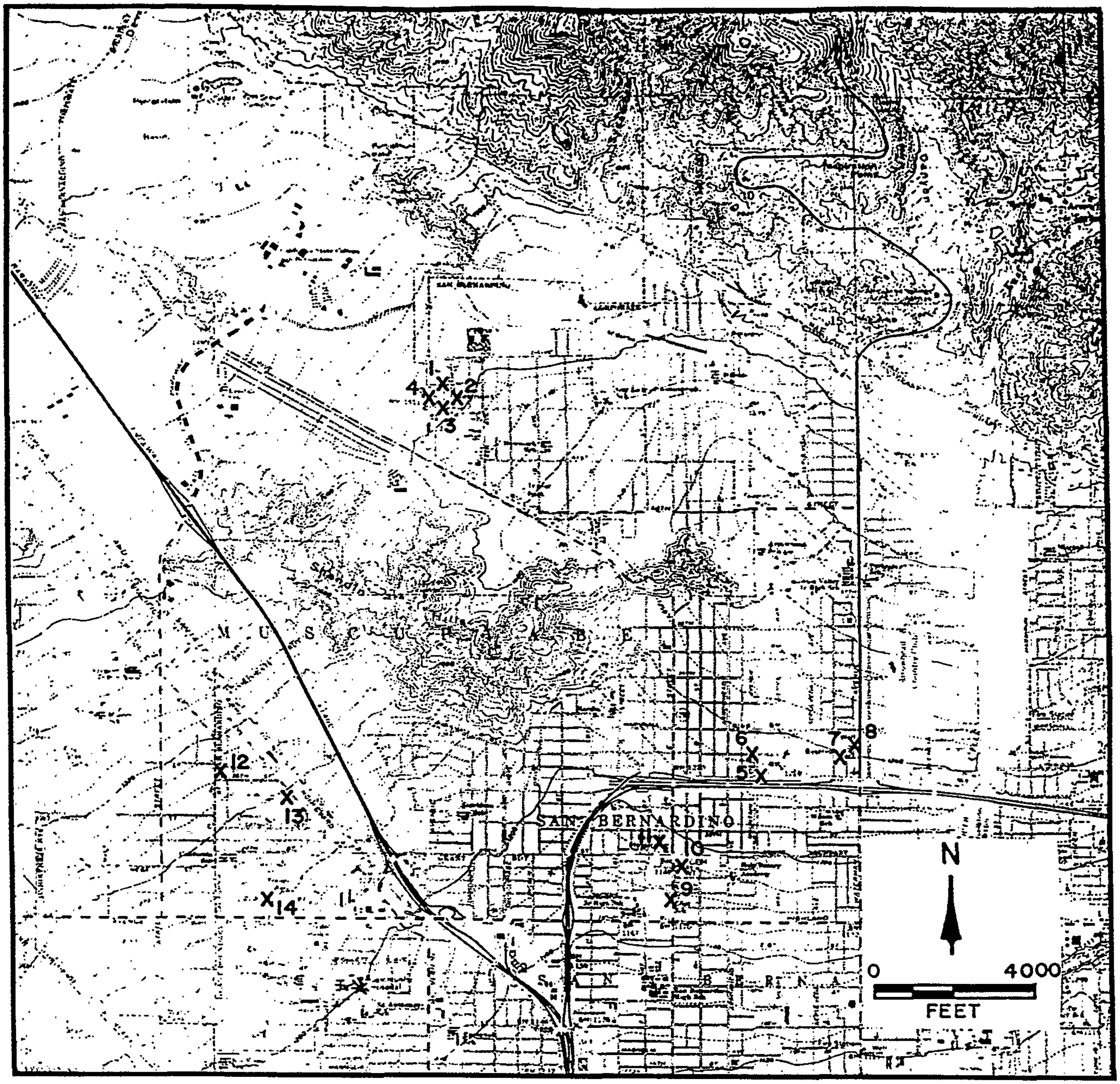


Figure 1. GROUNDWATER SUBBASINS AND THE STUDY AREA IN THE SANTA ANA RIVER BASIN



Local Well Names | (1) Newmark #1, (2) Newmark #2, (3) Newmark #3, (4) Newmark #4, (5) 30th and Mt. View, (6) 31st and Mt. View, (7) Leroy, (8) Waterman, (9) 23rd and N. "E" Street, (10) 25th and N. "E" Street, (11) 27th and Acacia, (12) Darby, (13) Colima, and (14) Gardena.

Figure 2. STUDY AREA AND LOCATION OF WELLS CLOSED BY TCE AND PCE CONTAMINATION

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TASK I: Identify Potential Contamination Sources

In the first task, URS prepared an exhaustive list of possible sources of TCE and PCE contamination and narrowed the list to a set of candidate source areas for subsequent field testing in later tasks. Specifically, the task objectives were to:

1. Perform a detailed search of available documents,
2. Interview public and private agencies,
3. Locate and interview former employees or neighbors of potential sources,
4. Prepare maps of TCE and PCE concentrations from available data, and
5. Prepare a screened list of candidate sources for further investigation.

By December 1985, all the Task I objectives were addressed; numerous data were compiled, and agencies and individuals were interviewed. Analyses revealed likely contamination source areas and patterns of water movements, field inspections identified dozens of potential sources, and analyses of all the available data led to a narrowed list of promising candidate areas for field investigations.

TASK II: Survey the Hydrogeology to Evaluate Plume Movements

All Task II objectives were achieved, including all hydrogeologic and groundwater subtasks. Specifically, the Task II objectives were:

1. Perform a literature search of hydrogeologic documents,
2. Compile the available geologic and groundwater data,
3. Correlate potential TCE or PCE sources with hydrogeologic data, and
4. Perform additional analyses to define hydrogeologic and water quality regimes.

Potential contamination sources were identified through reference documents, maps, other existing data, and personal contacts with current or former residents of the area.

Numerous hydrologic and geologic reports and maps were reviewed, spanning more than 80 years of investigations. Well depth and water quality data were compiled for a number of wells. The measurements of TCE and PCE were related to available hydrogeologic data to infer distances and directions of potential sources from the monitored wells. Other analyses were employed: 1) to seek other potential (abandoned) wells that may be useful for monitoring, and 2) to derive some detailed predictions of drawdown effects near several specific pumping wells that were contaminated.

In the second task, URS and its major subcontractor, ERM-West, characterized the hydrogeology of the study area to estimate likely routes and times of pollutant travel between candidate source areas and the wells where TCE and PCE were observed during the past 5 years.

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TASK III: Perform Field and Laboratory Investigations to Produce Supporting and Sustainable Evidence of TCE or PCE Sources

In the third task, URS (and its subcontractors) performed field and laboratory investigations to produce supporting and sustainable evidence of TCE/PCE sources. Specifically, the task objectives were to:

1. Obtain necessary sampling permits and clearances from property owners and appropriate agencies.
2. Perform on-site reconnaissance investigations.
3. Draft necessary subcontracts and prepare a quality assurance/quality control (QA/QC) plan.
4. Perform soil pore gas sampling.
5. Perform soil sampling.
6. Perform laboratory analyses of samples.
7. Complete and maintain documentation, such as contact forms, chain-of-custody forms, and daily sampling logs.

All the Task III objectives had been addressed by May 1986, and the Task III report was submitted. Samples were taken for soil pore gas at over 100 locations and soil was sampled at 7 target areas.

All field and laboratory investigations were performed in strict accordance with predetermined quality control/quality assurance procedures.

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Chapter 2.

SUMMARY OF FINDINGS

IDENTIFICATION OF POTENTIAL SOURCES

URS identified dozens of businesses and individuals in northwestern San Bernardino who may have been possible users or local-disposers of TCE and PCE. These establishments ranged from former military installations and airport complexes to individual homeowners who operate automobile or machinery repair shops in their backyards. The majority consisted of dry cleaners, automotive repair shops, and machine manufacturing or repair firms. A list of the potential TCE and PCE sources is given in Chapter 3.

FIELD INVESTIGATIONS

In February 1986 URS designed and implemented a monitoring program to seek TCE and PCE in soil pore gas at 100 stations. TCE was found at 7 of the 100 stations, and it was in relatively high concentrations at only 3 places. PCE was detectable at every site. Fairly high PCE concentrations were found at 7 sites, 3 of them high-TCE sites. The TCE and PCE results in pore gas are shown in Figures 40 to 43.

Sites with high pore gas levels were revisited for more direct evidence. Soils down to 40 feet were analyzed for TCE and PCE residues. Samples at 5-foot intervals in 18 different bore holes yielded detectable solvent residue on only a single sample. This one sample showed 0.1 milligram (mg) TCE per kilogram (kg) of soil, and it was from a bore hole at the one-time shop area at the now defunct San Bernardino Airport. This concentration was exactly at the detection limit of the analytical equipment for soil (0.1 mg/kg).

CONCLUSIONS

1. Significant amounts of TCE and PCE were found in soil pore gas throughout the study area. The significant sites were separated from one another by many sites where little trace of solvents could be found. No single source nor even a few dominant sources could be identified as being responsible for the contamination found in the 14 closed wells throughout the study area.

2. Numerous sources appear to have been responsible for the diverse pattern of solvent concentrations found.

3. Highest soil gas concentrations of both solvents occurred fairly near to, and downgradient of, the now-closed (private) San Bernardino and Shandin Hills Airports and Camp Ono, a former prisoner-of-war camp during World War II.

4. Direct evidence of responsible TCE or PCE sources would have to be collected through monitoring wells drilled to groundwater or through more closely-spaced soil pore gas measurements.

Chapter 3.

IDENTIFICATION OF POTENTIAL CONTAMINATION SOURCES

AGENCY DATA SOURCES CONTACTED

URS interviewed representatives from each of ten separate local and regional agencies about current and historical contamination levels and potential sources. Summaries of information obtained from all agencies contacted are given below.

Regional Water Quality Control Board

Files of chemical analysis records for TCE and PCE in wells were made available by Dixie Lass (Contract Manager) and Kamron Saremi, a Water Resource Control Engineer on the Board staff who has led field investigations of this contamination since the early 1980s. Maps of sampled-well locations were also provided. Particularly useful was a half-hour presentation by Mr. Saremi on the history of his own personal involvement in the monitoring of wells and his less formal reflections on potential sources or source-neighborhoods.

City of San Bernardino, Municipal Water Department

At the outset of the project, URS engineers met with the Municipal Water Department, who is the agency owning the majority of the water supply wells closed by the contamination now being sought. Considerable insight was gained in discussions with Mr. Herb Wessel, General Manager, Mr. Joe Stejskal, Director of Engineering, Construction and Maintenance, and Mr. Fred Ehemann, Water Quality Control Technician. The City provided data from its files on groundwater sampling results, well log data, groundwater levels, and previous hydrogeologic and engineering reports.

The Municipal Water Department is fairly well convinced that the contamination of its Newmark wellfield originated in the immediate neighborhood of the wells. Indeed the Department's officials have spoken to a former employee of a machine shop located at the site of the former San Bernardino Airport, adjacent to the Newmark wellfield. The employee freely admitted pouring solvents by the drumful into pits at the shop's site. The Department's interest in that anecdote appears to have ended with the identification of where the contaminants had likely originated. Mr. Wessel in particular was not inclined to seek the former owners or to pursue prosecution for damages because the business was long closed, the owners were gone, and the disposal practice used was fairly standard and not illegal at the time. Mr. Wessel likened the pursuit of responsible parties for long-past organics disposal practices to searching for other broadly based water users who contributed to salt build-up in groundwater.

City of Riverside, Water Department

Mr. Sam Johnson of Riverside's Water Department gave URS well logs and sampling data for many of the City's wells located in the Bunker Hill basin. These wells are south of the major area of focus of this study, and they have shown little or no contamination to date. But their records of water levels

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and geologic formations helped to complete the picture of regional groundwater flow.

State Department of Health Services

The San Bernardino office of the Department of Health Services was extremely cooperative and forthcoming with data. This is the agency whose sampling first identified TCE and PCE in the Bunker Hill basin, and it has the most extensive data base. Mr. Chet Anderson, Ms. Diana Barich, and Mr. Bill Gedney provided water quality sampling records for wells throughout the basin, construction logs for wells, depths to groundwater at various times and well locations, and other related useful information.

San Bernardino County, Department of Environmental Health Services

Mr. Peter Brierty of the Department of Environmental Health Services has been monitoring with interest the spread of TCE and PCE in local wells, and he is knowledgeable of historical development in the northwestern San Bernardino area which may have included potential sources of the contamination. Among the potential sources he mentioned were the San Bernardino Airport, Camp Ono -- a former prisoner-of-war camp for Italian World War II prisoners, and an Army munitions storage facility.

San Bernardino County, Land Management Department

Mr. Kenneth Guidry and Mr. William Gerke of the Office of Surveyor in the Land Management Department offered to make available aerial photographs they have on record of the study area. URS acquired several useful historic photos that were used to evaluate former commercial and military operations for evidence of waste discharge.

San Bernardino Valley Municipal Water District

Mr. Steven Stockton and Mr. Randy Van Gelder of the District's staff provided URS with a variety of hydrologic and geologic information concerning the Bunker Hill basin. Particularly useful were mapped groundwater level contours for 1977 and 1980 and several drilling logs for wells in the Bunker Hill Basin. The District also provided URS with reports on pumpage records, water levels, mathematical modeling efforts and results, and water quality data.

East Valley Water District

In an interview with Mr. Larry Rowe, General Manager, a great deal of information regarding potential sources of northwestern San Bernardino well contamination was obtained. The airport, various machine shops, fabricating plants, Camp Ono, and the munitions storage area were mentioned. Mr. Rowe's knowledge of the area stems from being a life-long resident of the region, a former water resources engineer with the SBVMWD and, as well as a consulting hydrologic engineer, and now Manager of the EVWD, located in an adjacent portion of the Bunker Hill basin. Moreover, his familiarity with TCE and PCE contamination has been heightened by the necessity to close one of the District's own supply wells as a result of PCE contamination in 1985. That particular well is isolated (far to the east) of the primary area of study in this investigation.

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Southern California Water Company

Three of the water supply wells that have been closed in the northwestern portion of San Bernardino belong to the Southern California Water Company. Southern California staff members in the Los Angeles office showed considerable interest in this study when contacted, and they referred the study team to the California Department of Health Services for records on their wells, available in the San Bernardino DOHS office. Those records were subsequently obtained from the State, and URS received permission to use such data in its study.

Muscoy Mutual Water Company

URS engineers met with numerous operating staff members and Directors of the Muscoy Mutual Water Company in early December. Records of AB 1803 sampling of water quality in their 5 wells were made available, and permission was given to review historic well boring data. Well construction data and water level data also provided were useful in constructing the hydrogeologic picture of the region in Task II, but the Company's wells -- which have shown no TCE or PCE contamination -- are actually located in the Rialto subbasin, just outside the study area.

CONTACTS WITH NEIGHBORHOOD RESIDENTS AND INFORMED CITIZENS

Many individuals who have lived and worked in the San Bernardino area, particularly in northwestern San Bernardino, were identified during Task 1 data collection efforts. Interviews were held with a number of these people, which produced still further leads to other individuals that recalled commercial establishments and cultural practices of the area from the 1940s and before.

In general, these interviews confirmed data URS had been acquiring throughout the process of interviewing agency representatives and collecting historic data. The individuals listed below provided further support to URS' effort in locating potential sources of contamination.

Chuck Palmer	The Sun
Ed Heil	Historian, the Elks Lodge
Fred Holladay	President, S.B. Historical Society
Claude Paine	Resident (since 1904)
Patricia Murphy	Resident (since 1931)

URS submitted the press release shown in Figure 3 for publication in The Sun during December 1985. The purpose was to contact former employees or neighbors of TCE or PCE-using commercial, industrial, or military establishments that may have additional information useful to this study. The article appeared in The Sun, on Sunday, December 22; and URS was contacted that morning by an individual who was willing to meet with URS staff the following Tuesday to point out locations of former TCE or PCE use during the 1950s and 1960s.

The information obtained from a field interview with that individual, who did not volunteer his name, is summarized below.

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Figure 3.

ANNOUNCEMENT FROM PAGE 8,
SECTION B OF THE SUN
DECEMBER 22, 1985

Inland Empire

The Sun San Bernardino, California

East Valley Edition

Redlands, Yucaipa, Mentone
Loma Linda, Calimesa

Sunday, Dec. 22, 1985

Firm seeks source
of contamination.
See Page 8.

B

People sought who may know of solvent dumping

SAN BERNARDINO — People who may know about the use and possible spilling or dumping of industrial solvents in northwest San Bernardino are being urged to contact a local engineering firm that is surveying the area.

The URS Company, which has contracted with the Santa Ana Regional Water Quality Control Board to attempt to find the source of contamination in San Bernardino's groundwater, is seeking people who may know where solvents were used between the years 1940 and 1980.

Contamination by trichloroethylene — TCE — and perchloroethylene — PCE — has required San Bernardino's Water Department to take 11 of its water wells out of service.

It is believed the pollution entered the soil at one or more locations in north San Bernardino, filtered into the underground Bunker Hill Basin and began spreading south. The plume of contamination has shut down wells located in a swath that begins around 48th Street and Western Avenue and spreads south to at least 23rd and E streets.

Wells in the vicinity of Highland Avenue, Mount Vernon Avenue and 19th Street are also showing very minor signs of contamination, possibly from a separate pollution source, city officials have said.

URS has recently begun a program of soil testing and research to locate businesses that may have used the solvents and areas where they may have gotten into the soil, said Michael Sonnen of URS. Pinpointing the location of the solvents may help with a clean up program, he said.

The types of businesses that may have used such chemicals include dry cleaners, machine shops, fabricating plants, auto repair shops and some military and civilian aircraft cleaning and repair operations.

The area URS is interested in extends south from Devore to Base Line and is bounded on either side by Cajon Boulevard-Kendall Drive and Waterman Avenue.

People with information about the chemicals can contact Sonnen or Jack Chen at the URS Co., (714) 381-4566.

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At point #2 shown in Figure 4, he described the area to the east as far as the ditch (near point #4) as the old airport shop area and the area across the street to the west as the area where hangars and the runways had been. He described the entire area as a place where a wide variety of solvent use and liquid waste storage, leaking, and surreptitious dumping had taken place for years (roughly 1958 to 1963) after the airport operation (roughly 1940s to 1958) had ceased.

The anonymous source recalled numerous tanker trucks being in the area at night, dumping their contents all over this area, often along the old runways. Many of these, though not all, were signed as belonging to cesspool or septic-tank pumping and disposal companies. He speculated that they were avoiding a somewhat longer trek "up the mountain" and a nominal fee for dumping at an approved disposal site. During the period of night-time dumping, there were to be seen along the (then) dirt roads and old runways "as many as 15 trucks at a time."

The man also described five or so businesses located on the east side of the street (now Little Mountain Drive) as having used (1958-63) TCE and other solvents and paint thinners. These included trucking companies, a crane outfit, two metal fabricators, and a machine shop. One of these businesses was a heavy machinery repair operation. He referred to the central feature of this operation as the "CAT Pit" which consisted of ramps over a 20-foot-wide, 14-foot-deep pit onto which Caterpiller and other heavy construction equipment or trucks were driven for service. Oil and other fluids were drained from the machinery into the pit, and "TCE vapor" was used to clean the equipment. He remembered seeing drums there marked "TCE." Oil and other fluids in the pit accumulated "as much as 6 feet deep at times."

On the north side of the present housing development, an old fire engine had been abandoned, which leaked gasoline onto the ground until emptied. A tank of what the man called at one point "750 gallons of aircraft cleaning fluid" [PCE has been so used] and what he called at another time "750 gallons of paint thinner or other solvent" had been abandoned; it had leaked onto the ground "for years" in the 1958 to 1960 period.

In the shop area to the east of Little Mountain Drive (now residential housing) there had been storage tanks for gasoline and for aircraft fuel.

This man also took URS staff to the ditch-crossing on 48th Street (point #3 in the figure) so he could show us the "CAT Pit." Upon reaching that point, he told us that 48th Street was "for a while" 42nd Street and that the old airport shop area on the north side of the street had at various times the addresses: 900 West 42nd Street and 1303 West 48th Street.

He led the party up the west bank of the flood control ditch that separates the housing development from the Newmark wellfield belonging to the City of San Bernardino. Roughly 200 feet north of 48th Street he pointed out a house, stating, "The CAT Pit was right underneath that house." (See point #4 in the figure.) He recounted that the pit eventually became plugged with motor oil and grease, and the site was abandoned. In 1965 or 1966, he recalled, the pit was "dug out," and the diggings were hauled over to the runway area to the west and dumped.

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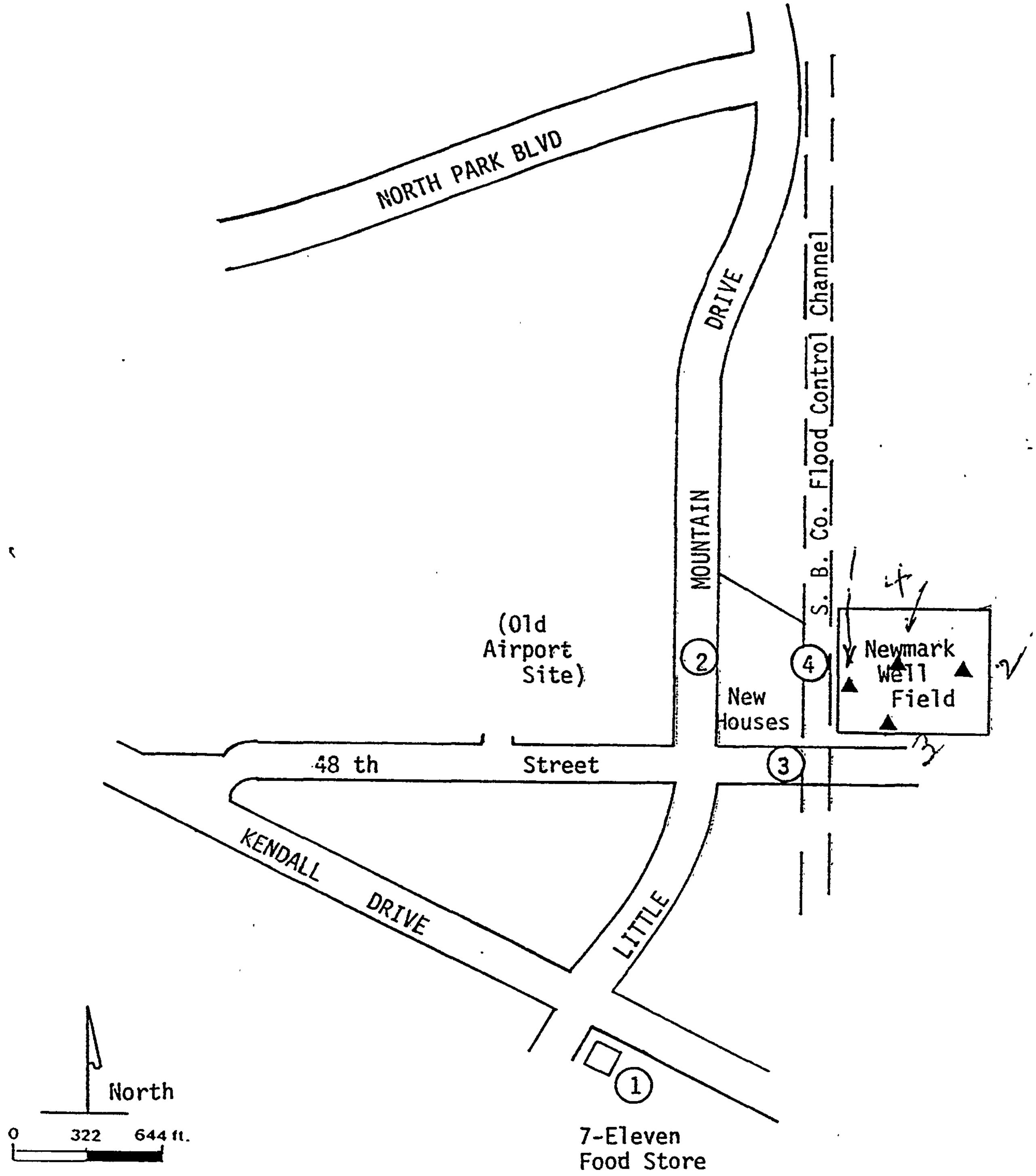

Figure 4. POINTS OF INTEREST INDICATED DURING FIELD INTERVIEW

▲ Wells

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The alleged location of the "CAT Pit" is roughly 150 feet west of the Newmark wellfield. The house pointed out is directly west of three white posts which are closely-spaced, roughly 8" x 8" timbers standing vertically in the top of the east bank of the flood control ditch.

The following indications suggest the relative reliability of the above-summarized information that URS received anonymously. Our interviewee reported at various times that he was "around every day" (probably between 1958-1963) and that he had repeatedly seen trucks dumping in this area at night. He also told stories of other unusual but unrelated incidences in the area. He probably had lived nearby and had watched the day and night activities over a period of years. Still further, he purports to have known the exact address of the airport shop at two different periods. And lastly, and probably most importantly, one of the reasons he agreed to show us places on the ground but not to give us names, including his own, was "because I know some of those fellas." He also alleged that the CAT Pit was owned by "somebody in New York" but it was "operated by a lawyer in San Bernardino."

Figure 5 is a reproduction of a drawing that he sketched for us, showing his recollection of the airport shop layout. The "brushy area" in the southwest corner of the drawing, now covered by houses, is an area where he had alleged that transformer fluid was drained from the backs of trucks on several occasions for dust control.

ADDITIONAL CONTACTS REGARDING POTENTIAL SOURCES

Dr. Bruce Halstead

On December 26th, URS received a letter and 30 pages or so of backup materials from Dr. Bruce Halstead, who had called on December 23rd in response to the article in The Sun. Dr. Halstead's letter lamented pollution in the southern California area generally, particularly waste discharges to the ocean. Additionally his letter alleges, "We photographed trucks dumping wastes out at [sic] Norton Air Force Base into the Chino sewage outlet and in 1970 Norton Air Force Base alone dumped 1.2 million gallons of these wastes. Enclosed is a list of these wastes, which reads like a who's who in toxicology." [The list of 94 compounds does not include either TCE or PCE.] Dr. Halstead is the Director of the World Life Research Institute in Colton.

Anonymous Employee

On December 31st, URS received a call from an employee of a roofing tile manufacturing company located between Redlands and the south side of Norton Air Force Base [out of this project's study area]. This man wanted to report that his employer's company had for 5 or 6 years been dumping solvents, waste oils, and paint slurries into a large pit on their property. Despite the fact that in recent times the pit has been pumped out once or twice a month by a disposal company, he was concerned about the materials that had been placed there for years. Former phone calls of his to both fire and police departments about this situation had been met with claims of: "It's not our job." While this site is not in the study area and almost certainly is not related to the contamination of the wells studied here, which are miles up-gradient, nonetheless the potential seriousness of the practice was apparently evident

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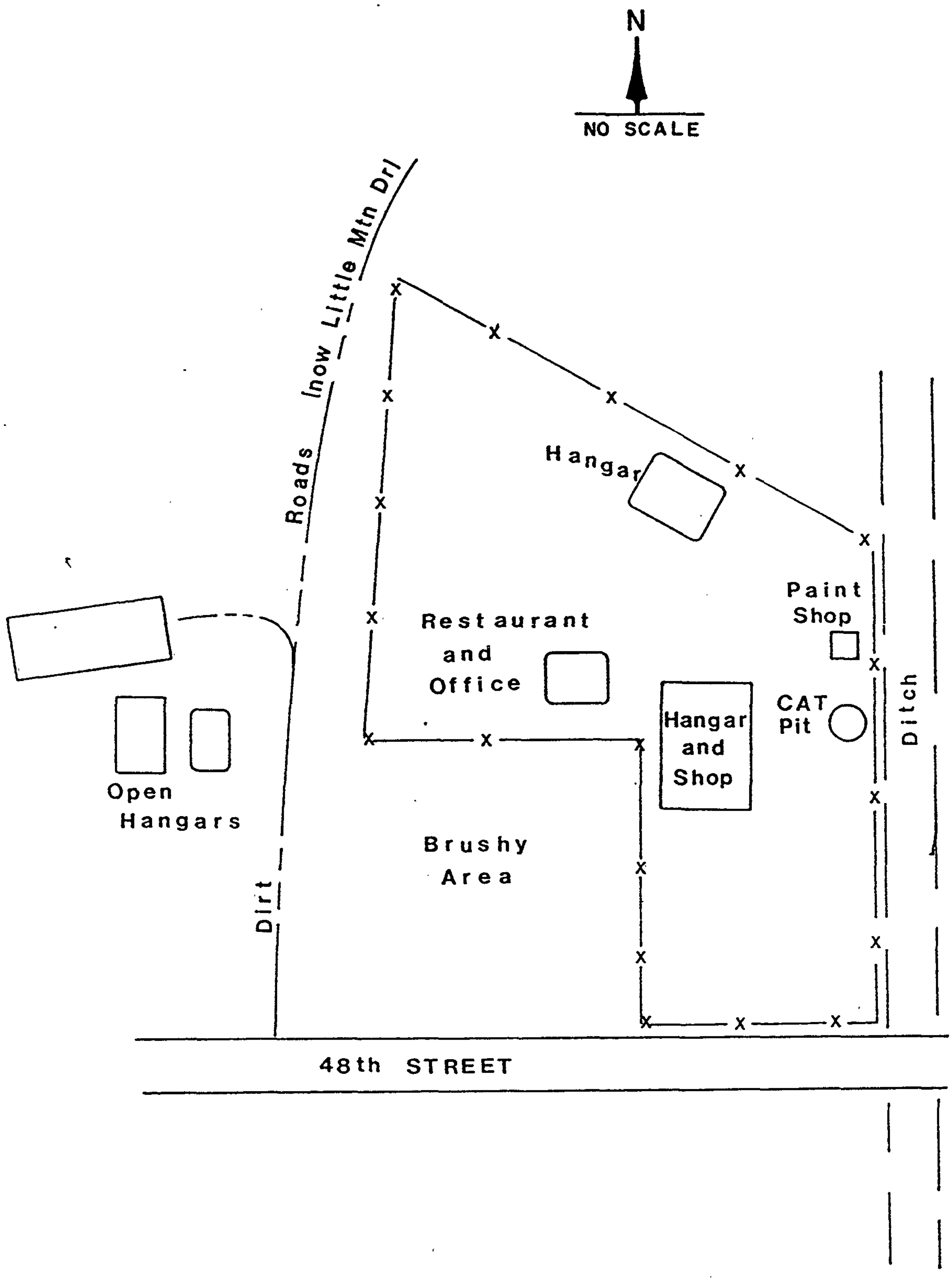

Figure 5. REPRODUCTION OF A SKETCH DRAWN BY THE URS INTERVIEWEE

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to the employer who eventually had the pit backhoed of "foul-smelling" materials, according to our source, at 4:00 o'clock one morning.

Anonymous "Bulk Plant" Employee

On the 27th of December, URS was called by a man who reported working at a "Bulk Plant" on 4th Street west of Mt. Vernon during the period 1961 to 1967. This plant was apparently closed in 1970 but had been in operation for 40 years, processing oils, fuels, paints, and paint thinners or other solvents. Tank car quantities of these materials were delivered to the site by rail. As part of the operation, clients brought used 55-gallon drums to the plant which were exchanged for filled drums; the empty or near-empty drums were flushed with water, and the flushings went on the ground in the plant yard. [This site is several miles south -- downgradient -- from the wells affected thus far by TCE and PCE.]

AVAILABLE DOCUMENTS

During the study effort, URS collected a significant amount of water quality data and analyses results produced by other investigators concerning TCE and PCE contamination, hydrogeologic data on specific wells and the region generally, and mathematical modeling studies performed previously. A bibliography of all material on file appears in Appendix A.

DATA BASE OF CANDIDATE SOURCES

Following the two field investigations, URS perused old telephone books of the General Telephone Company of California (GTE), dating back to the middle 1940s. We noted listed establishments under the yellow pages headings of airports, aircraft repair, auto (and auto body) repair, auto painting, dry cleaners, machine shops, refrigeration manufacture or supply, and steel manufacture or fabrication.

All the establishments identified from our field inspection and records searches have been entered into a data base. A printout of this data base is listed in Table 1. Entry of any establishment on this list implies nothing whatsoever about TCE or PCE discharge into the local environment by that establishment. It is not implied that any given firm on the list now uses or ever used TCE or PCE in its enterprise or that any listed firm engaged in onsite (legal or illegal) dumping or disposal of these solvents.

It is common knowledge, however, that TCE and PCE were routinely used across the country among the business types represented on the list. The value of the 54 compiled names and locations is the indication they give of how numerous and widespread these kinds of industries have been. Stated another way, the list suggests that water supply wells located in urban areas today are operating at fairly substantial risk of eventual contamination from even an accidental spill of toxic or hazardous substances located virtually all around them. The risk in the Bunker Hill basin is certainly real, as attested by the 14 closed wells in northwestern San Bernardino, another closed temporarily in the East Valley Water District area, and still others that remain closed near Redlands.

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Table 1.

POSSIBLE SOURCES OF TCE OR PCE USE OR STORAGE

Created in December 1985
Updated in June 1986

No	Business Type	Address or Current Location	Estimated Years of Operation
	AIRPORTS		
1	Shandin Hills Airport	27th & Mt. Vernon	Before 1940-1944
2	San Bernardino Airport	900 W. 42nd Street	1948-1951
	AIRCRAFT REPAIR		
1	Stinson Authorized Sales and Service	900 W. 42nd Street	1948
2	Aircraft Repair	3696 Vermont Street	1958
	AUTO BODY REPAIR & PAINTING		
1	Alvin's Sierra Way Garage	4161 N. Sierra Way	1977
2	Dudley's Auto Service	3997 N. Sierra Way	1977-1983
3	German Auto Haus	596 W. 40th Street	1977-present
4	Glenn's Auto Repair	331 W. 40th Street	1977-present
5	Ike's D & I Automotive	3308 N. E Street	1977-present
6	Lester's Auto Repair	3610 Cajon	1977-1978
7	Rod's Auto Service	3196 N. E Street	1977-1978
8	Advanced Auto Body Shop	3550 Cajon	1970-1974
9	Contemporary Paint and Body Shop	3550 Cajon	1975-1979
10	J & M Paint & Body Shop	3550 Cajon	1979-present
11	Bruce's Garage and Towing Service	19407 Cajon	1977-present
12	Reave's Service	4009 N. Sierra Way	1978-1982
13	Parker's Auto Service	3610 Cajon	Unknown-present
14	D J's Automotive	466 W. 40th Street	Unknown-present
15	Carole's Auto Repair	434 W. 40th Street	Unknown-present
16	Sierra Way Auto	3997 N. Sierra Way	1983-present
17	Chick's Garage	598 W. 42nd Street	1958-unknown
18	Sav-Mor Auto Paint	3265 N. E Street	Unknown-1984
19	Lew's Transmissions	3780 N. Mountain View	Unknown-present
	CLEANERS		
1	Boulevard Cleaners	3267 N. E Street	1948-1980
2	Effie's	2175 N. Sierra Way	1951-1972
3	Esquire	2140 N. E Street	1948-1969
4	Ideal Cleaners	4352 N. Sierra Way	1964-1967
5	Ideal Cleaners	2175 N. Sierra Way	1968-1969
6	Sahara Cleaners	201 E. 40th Street	1969-1970
7	Sahara Cleaners	264 E. 40th Street	1970-present
8	North End Laundry & Dry Cleaners	134 W. 40th Street	1975-1983

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Table 1, Continued, Page 2 of 2

No	Business Type	Address or Current Location	Estimated Years of Operation
9	One Hour Martinizing	173 E. 40th Street	1965-present
10	Royal Cleaners & Laundry	267 E. 40th Street	1970-1973
11	College Park Cleaners	974 W. Kendall	Unknown-present
12	Norge Equipped Laundry and Cleaning Village	444 W. Highland	Unknown-present
13	Sierra Laundry and Dry Cleaners	2175 Sierra Way	1948-1983
14	Sweet Kleen Cleaners	431 W. Highland Ave.	1953-present
15	One Hour Fabric Care	1090 W. Highland Ave.	Unknown-present
	MACHINE SHOPS		
1	Abbott Machine & Welding	337 W. 40th Street	1961-present
2	Anco	19851 Cajon	1980-present
3	Walter F. G. & Son	5770 Industrial Pky.	Unknown-1983
	MILITARY OPERATIONS		
1	Camp Ono	I-215, north of University Pky.	1941-unknown
2	Bomb Manufacturing Fac.	NW Section of Shandin Hills Golf Course	1942-unknown
	REFRIGERATION MANUFACTURE/SUPPLY		
1	Refrigeration Service Co.	592 W. 40th Street	Before 1969-present
	STEEL MANUFACTURE/FABRICATION		
1	Ansco Steel Company	20225 Kendall	1970-1977
2	Armor Rolling Mill	20225 Kendall	1978-1982
3	Alden	20225 Kendall	1980-present
4	Portofab	1300 W. 48th	1978-1979
5	Labor Contractors Company	1970 N. State Street	Unknown-present
	MISCELLANEOUS		
1	Scott Specialty Gases	2600 Cajon	Unknown-present
2	Unicorn Abrasives & Supply Company	3552 Cajon	Unknown-present
3	A junk yard	West side of Cajon, opposite Ind. Pky.	Unknown-present
4	A & A Manufacturing	17760 Cajon	Unknown-present
5	Potter Residence	19346 Kendall	Unknown-present
6	J. Putnam Henck	550 E. 40th St.	1953-present
7	A "Bulk Plant" (waste oil, paints, etc.)	4th St. W. of Mt. Vernon	1930s-1970
8	A "CAT Pit" (a dumping site)	900 W. 42nd St. or 1303 W. 48th St.	1958-1963

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CANDIDATE SOURCE LOCATIONS

The locations of all the identified candidate sources are plotted in Figures 6 through 9, at the end of this chapter. Also shown are the 14 closed municipal water supply wells.

WATER QUALITY DATA AND THEIR IMPLICATIONS

Analytical results for TCE and PCE in the closed water wells and others were obtained from the Regional Board, the State Department of Health Services, and the San Bernardino Municipal Water Department. For those wells that showed high levels of TCE or PCE in the first round of testing (1980), monitoring has been continued ever since. These wells include the 11 closed wells of the City and 3 closed wells belonging to the Southern California Water Company. Wells that showed trace amounts of contamination initially are still sampled sporadically or as often as deemed necessary.

Because the available data are limited, contour mapping of TCE and PCE concentrations was found to be less than fruitful. Therefore, the available data have simply been averaged for the years between 1980 and 1984 and for each quarter of 1985. These data have been plotted in Figures 10 through 27.

The chronological maps of TCE and PCE -- one set each for TCE and PCE -- indicate that the highest contaminant concentrations were first found (1980) at the north side of the City, in the Newmark wellfield. Concentrations were lower but significant at the same time in wells in the Delmann Heights area (mainly in the Darby, Colima, and Gardena wells). Gradually the contaminants showed up in wells on the southern and southeastern sides of the Shandin Hills. This apparent southerly and southeasterly movement is generally in agreement with the groundwater flow directions around the Shandin Hills. It was, then, reasonable for the City and others to have speculated that the sources of contamination were located upgradient of the Newmark wells and the Delmann Heights wells. Specifically, the San Bernardino Airport (a private airport) and Camp Ono appeared to be very plausible sources. It was also possible that sources northwest of Muscoy contributed to the contamination in the Delmann Heights wells.

However, it is also to be noted from the TCE and PCE concentration maps and the plots with time in the following section that large fluctuations of TCE and PCE have occurred along the possible plume directions and at virtually every well that was monitored. These spatial and temporal changes of TCE and PCE suggest that many discrete plumes of contamination may be flowing in the general groundwater system in the study area. They may have been introduced into the system from many or at least several sources, and the concentrations have probably oscillated as a result of fluctuations in groundwater levels and/or the variations in recharge which mobilized the contaminants and incorporated them into the saturated zone. It is also to be noted that the wells have been monitored (sampled) by extracting water with production pumps which probably volatilized (lost) portions of the solvents in various degrees from sample-to-sample, and all the wells sampled are perforated (extract groundwater) at unique intervals in the aquifer materials. In short,

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seemingly apparent regionalized plume movement over the relatively short period from 1980, when sampling began for TCE and PCE, to 1985 is largely illusory and frought with numerous complications and sources of error. In this regard, it is shown later herein that PCE movement across the Newmark Wellfield (active until 1983) -- a distance of only several hundred feet -- took several years. The four wells were operated in the 1978-1983 period at 700 to 1300 gallons per minute each (about 4000 gpm total), which should have accelerated solvent movement to substantially higher travel velocities than would occur in a regional flow field.

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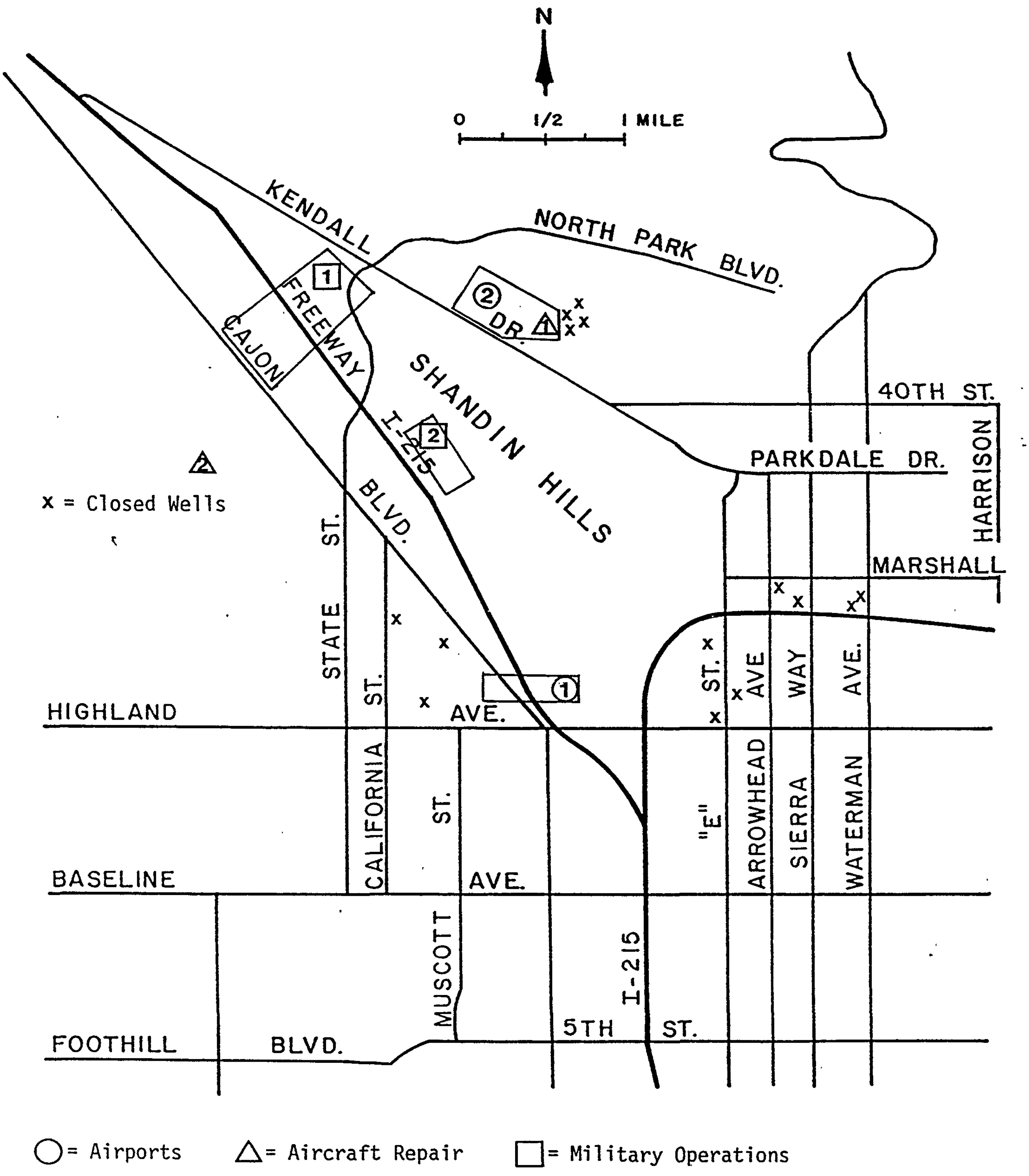

Figure 6. AIRPORTS, AIRCRAFT REPAIR, AND MILITARY OPERATIONS ON NUMBERED POSSIBLE SOURCE LIST

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CITY00166

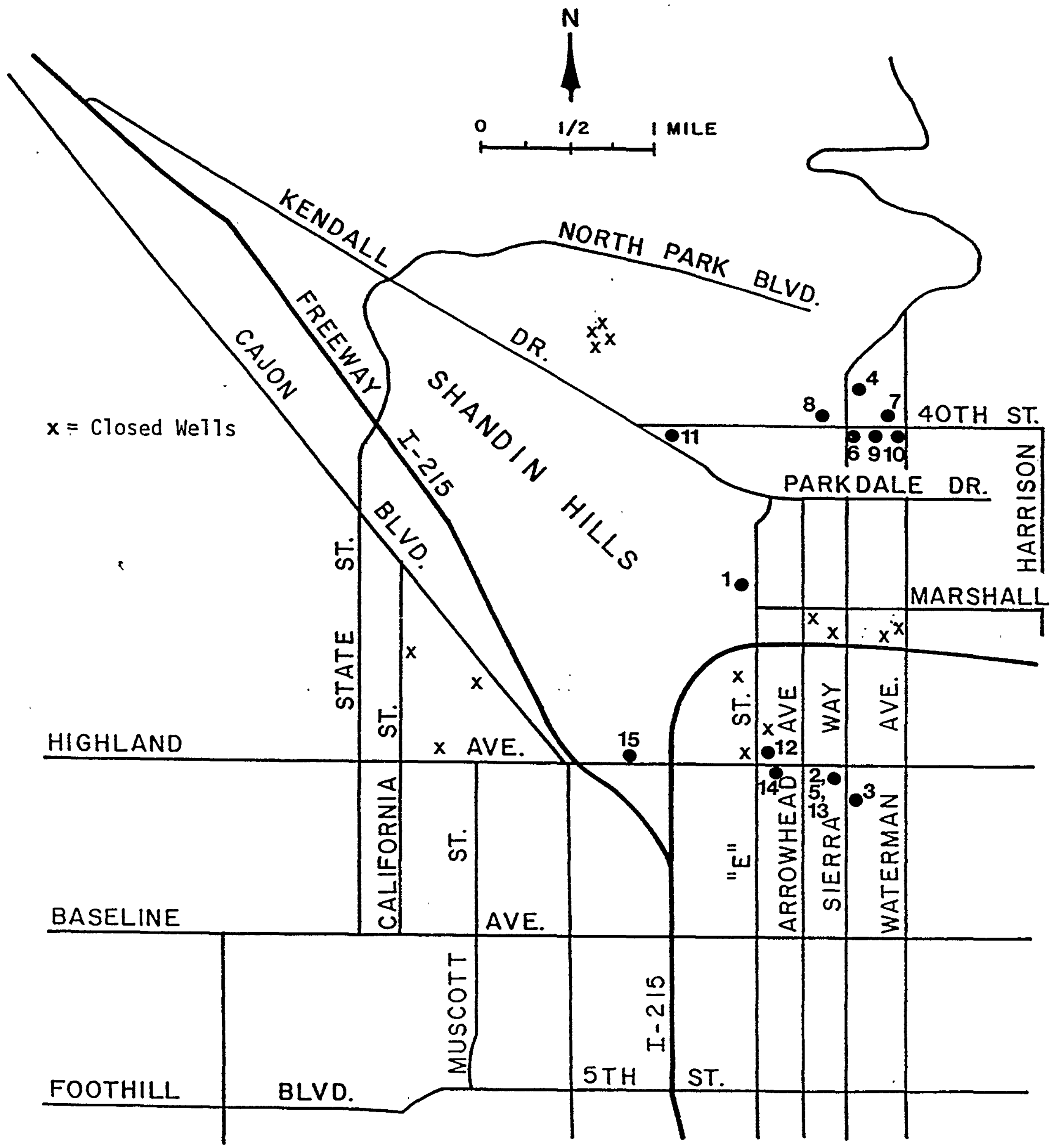

Figure 7. DRY CLEANING SHOPS ON NUMBERED POSSIBLE SOURCE LIST

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CITY00167

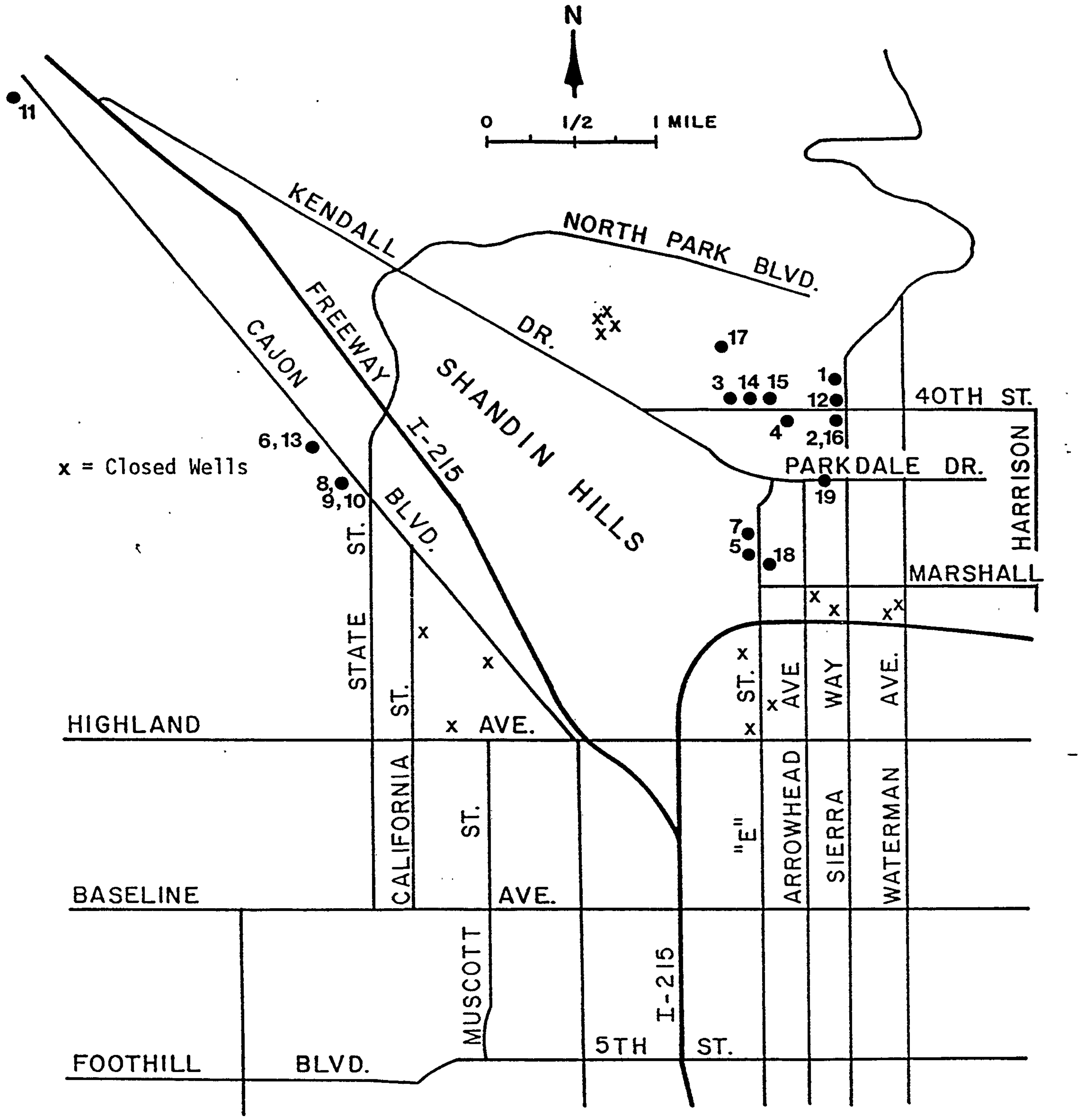

Figure 8. AUTO BODY REPAIR AND PAINTING SHOPS ON POSSIBLE SOURCE LIST

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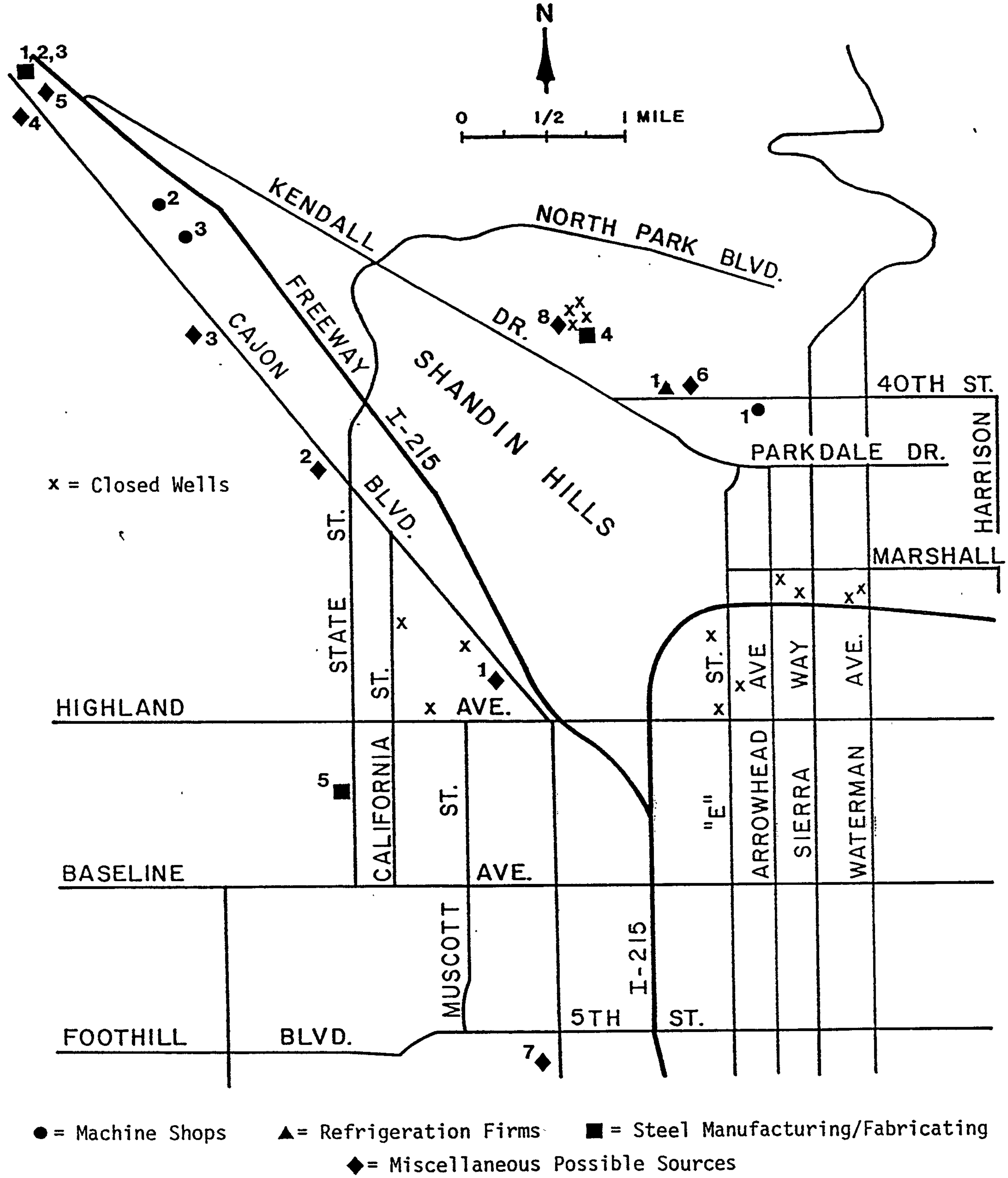

Figure 9. POSSIBLE MACHINE-SHOP, REFRIGERATION, STEEL, AND MISCELLANEOUS SOURCES ON NUMBERED SOURCE LIST

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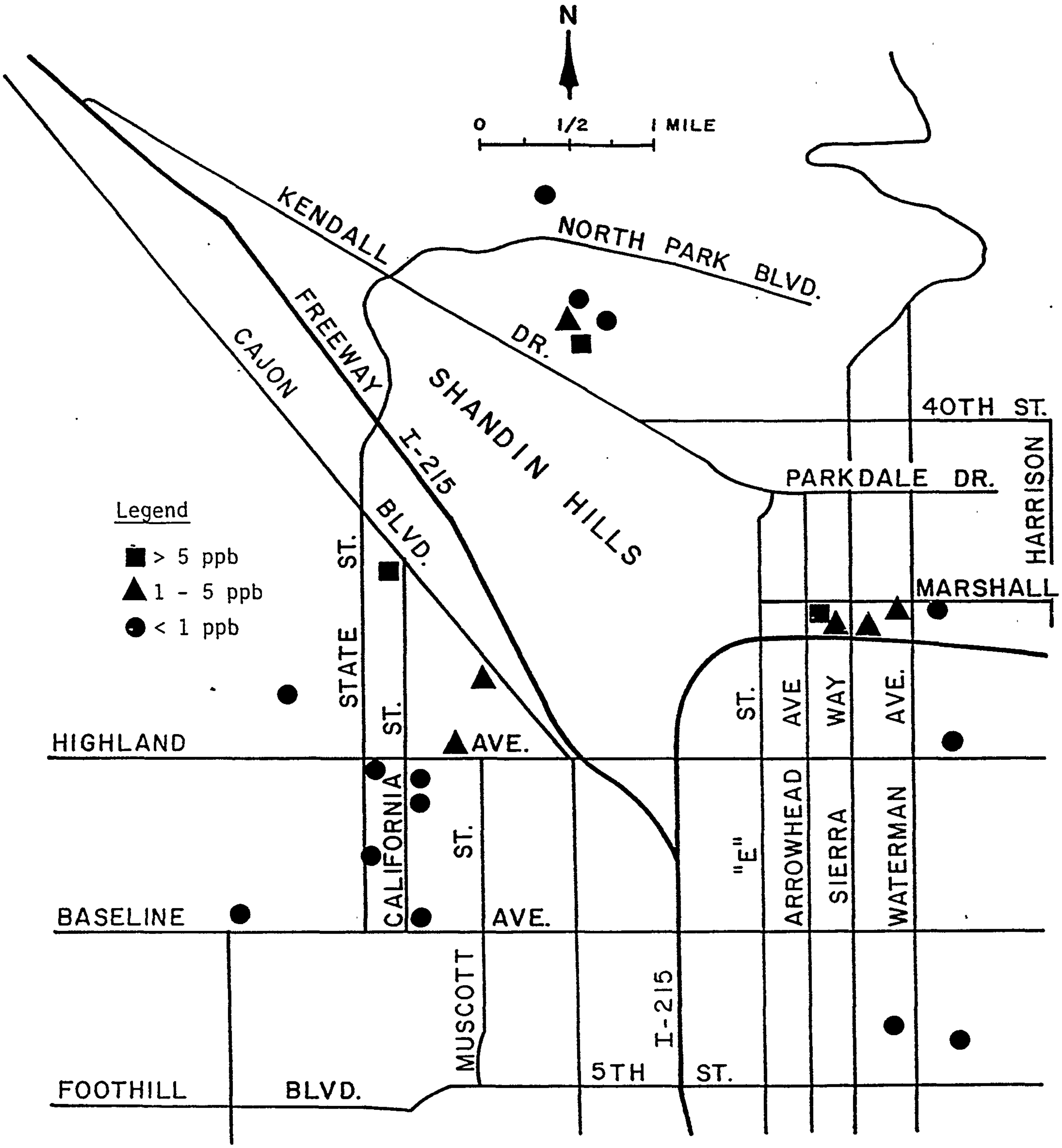
CITY00169



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 10. TCE CONCENTRATION MAP FOR THE YEAR 1980

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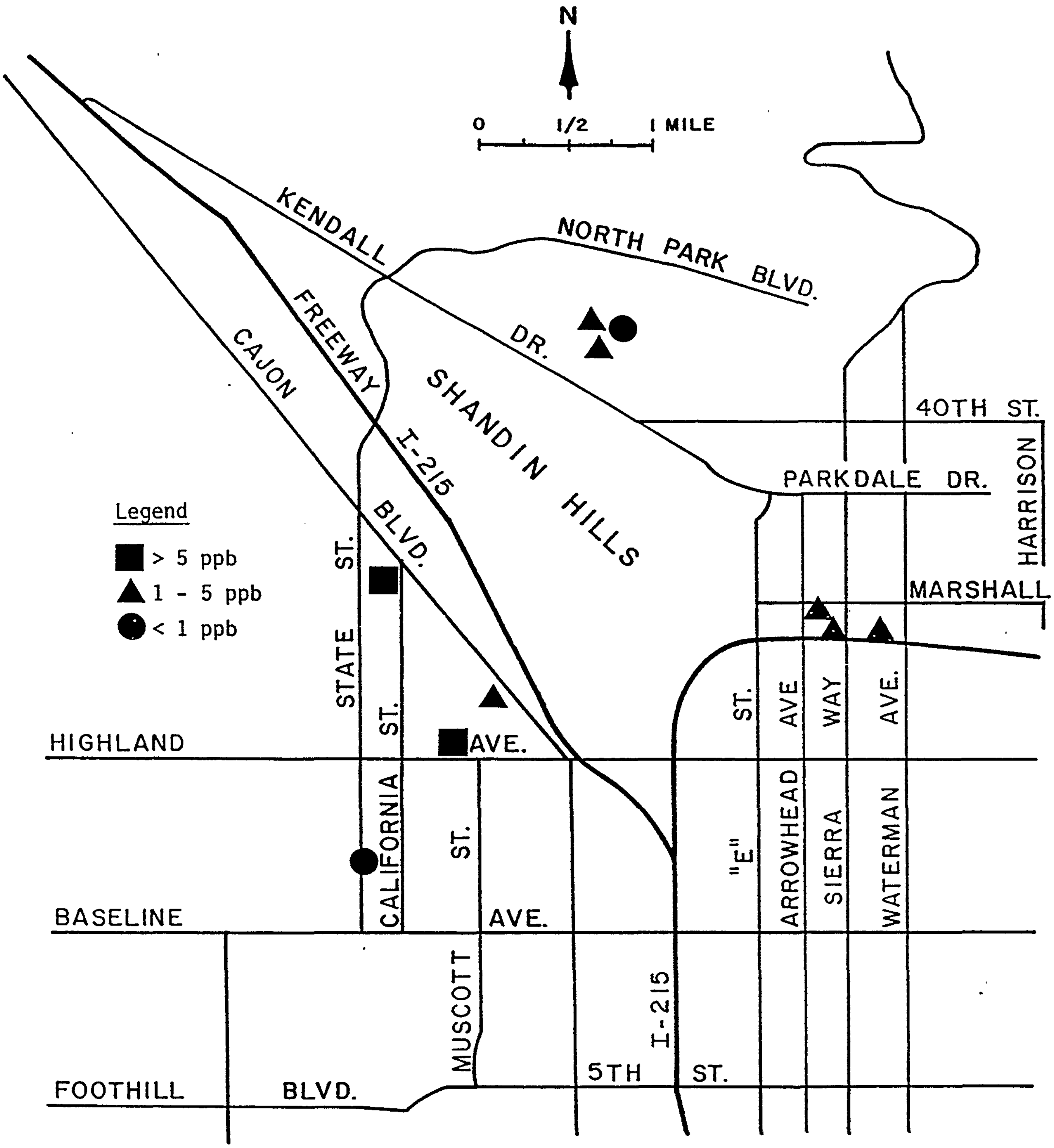

Note: See Figure 28 and Table 3 for Well Identifications.

Figure 11. TCE CONCENTRATION MAP FOR THE YEAR 1981

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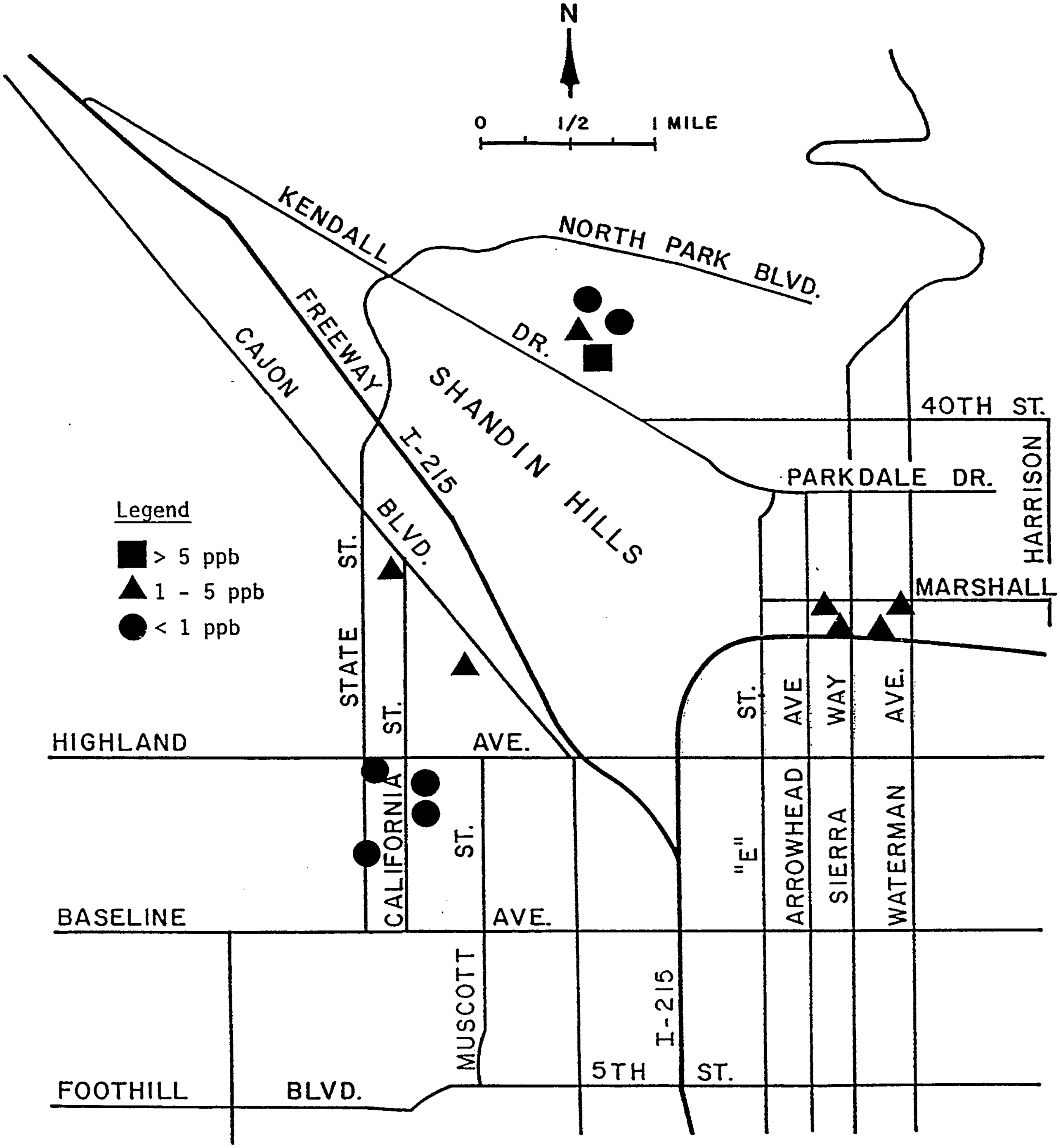
CITY00171



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 12. TCE CONCENTRATION MAP FOR THE YEAR 1982

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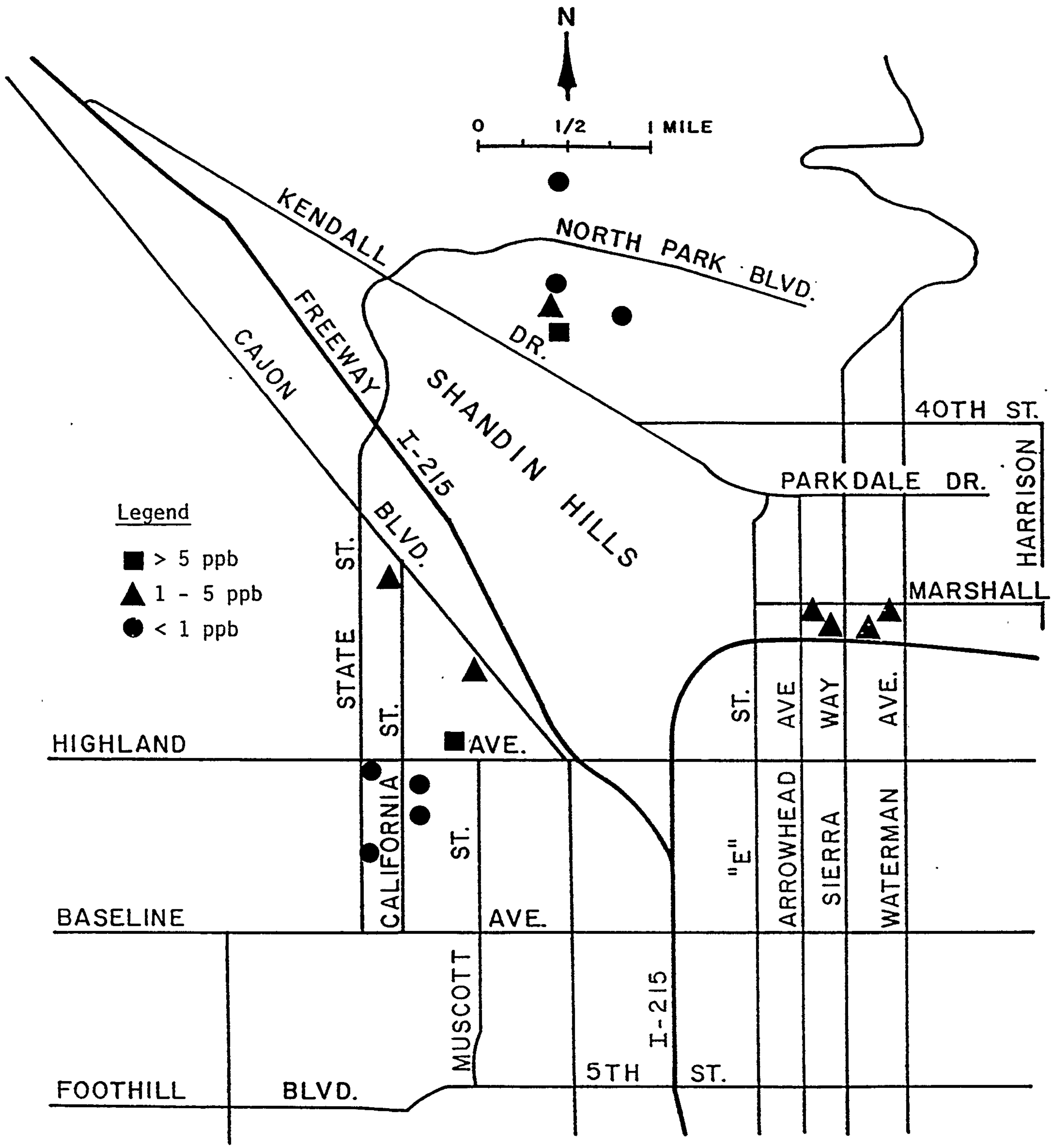
CITY00172



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 13. TCE CONCENTRATION MAP FOR THE YEAR 1983

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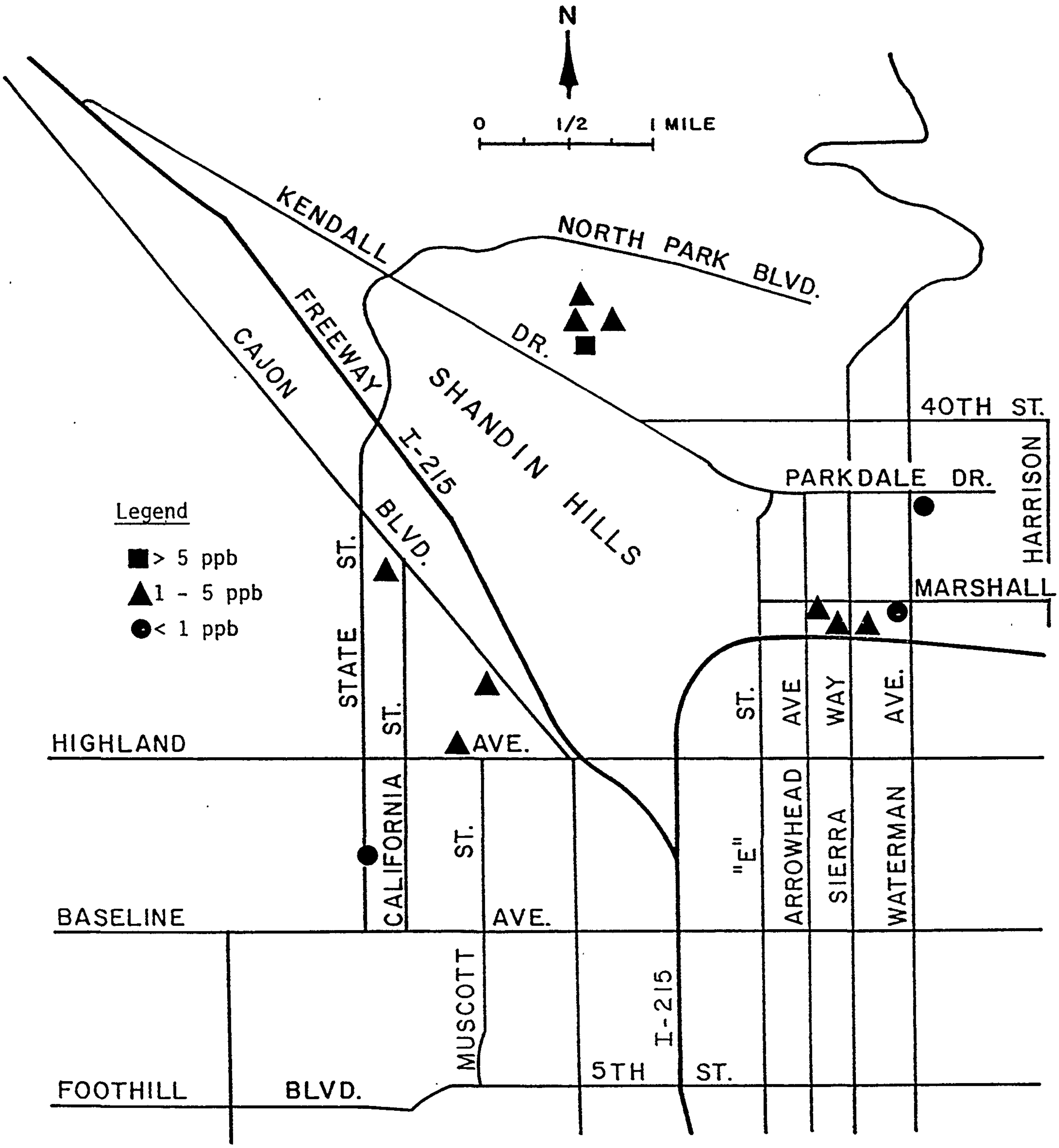
CITY00173



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 14. TCE CONCENTRATION MAP FOR THE YEAR 1984

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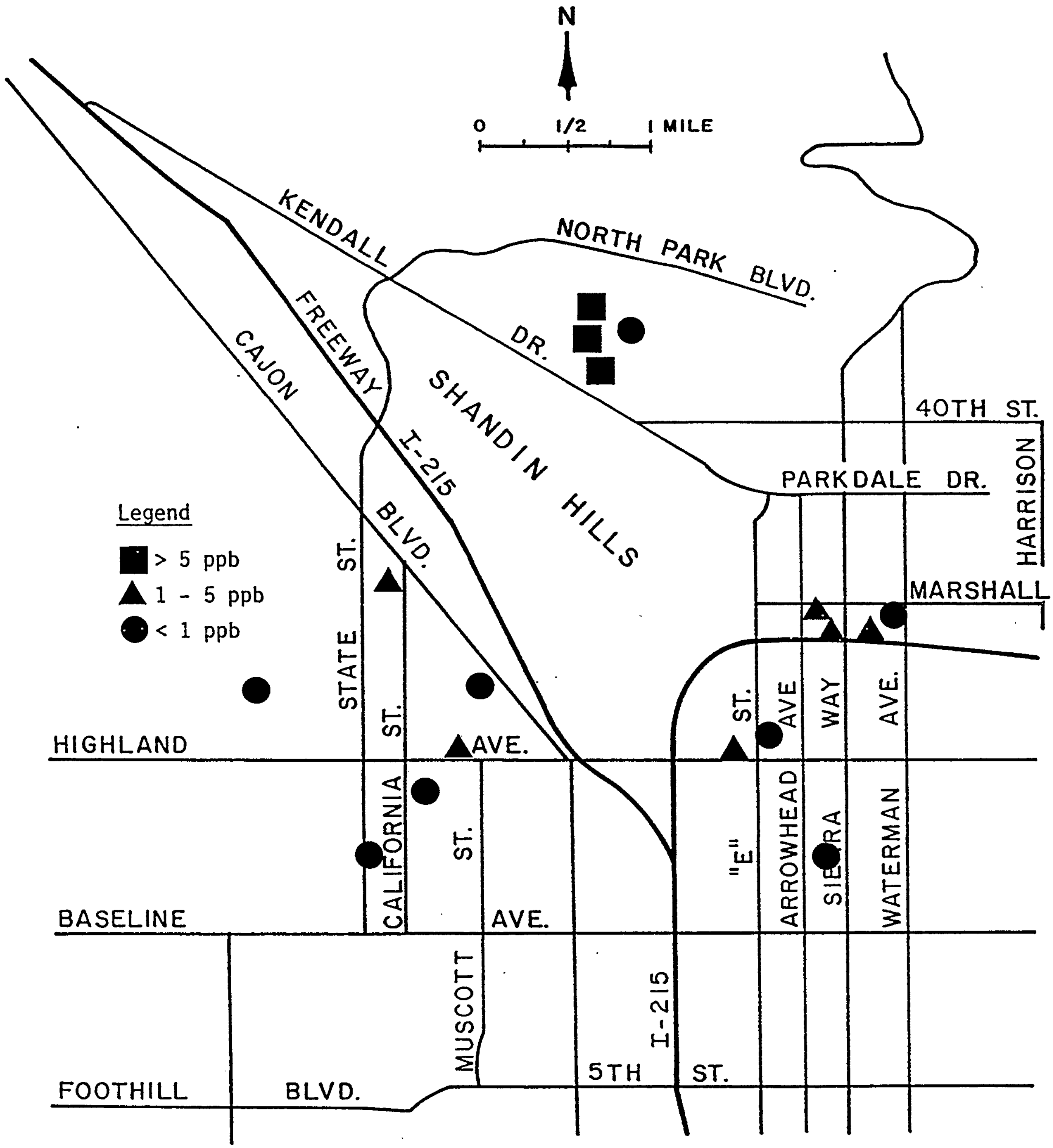

Note: See Figure 28 and Table 3 for Well Identifications.

Figure 15. TCE CONCENTRATION MAP FOR THE FIRST QUARTER OF 1985

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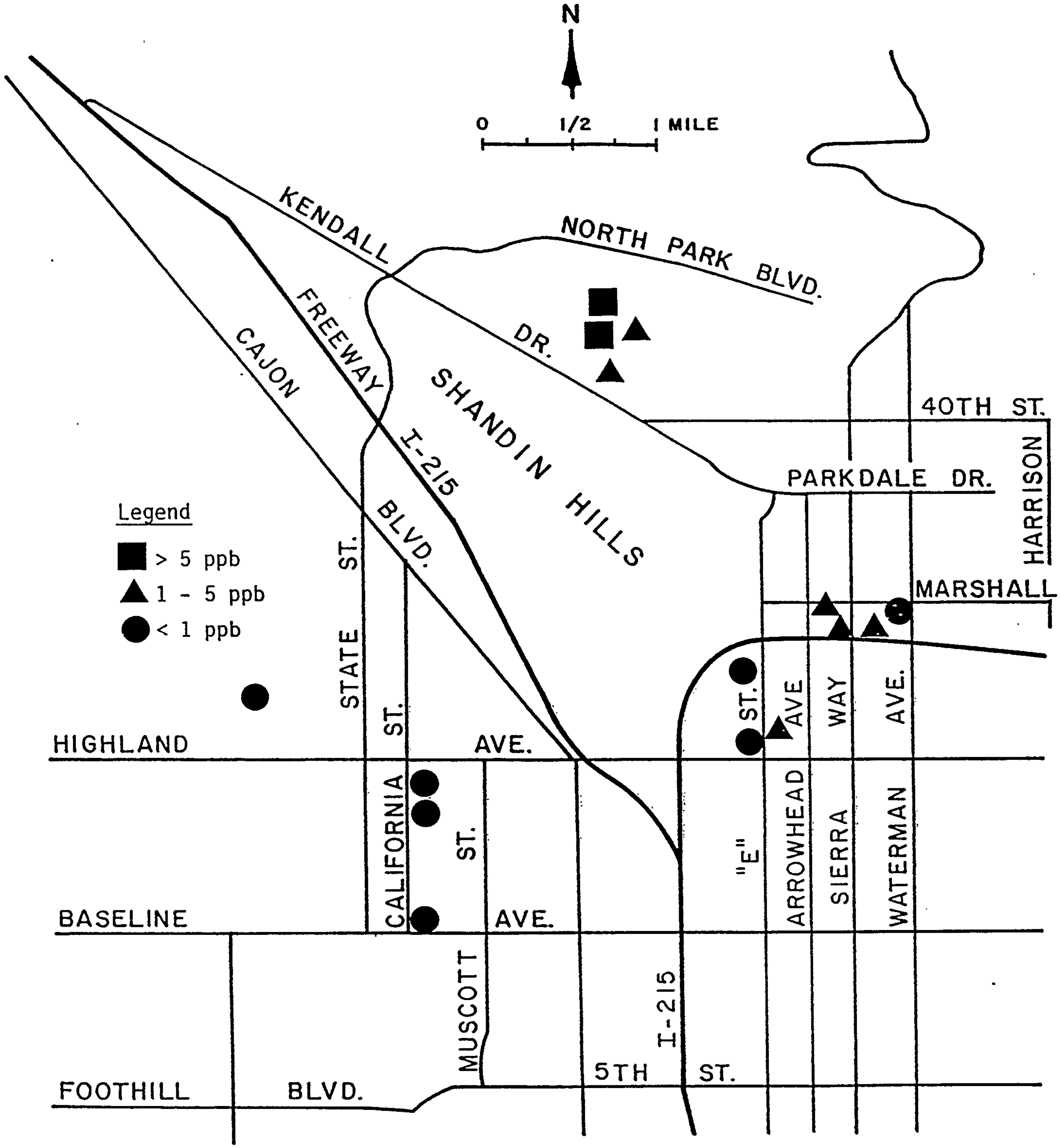

Note: See Figure 28 and Table 3 for Well Identifications.

Figure 16. TCE CONCENTRATION MAP FOR THE SECOND QUARTER OF 1985

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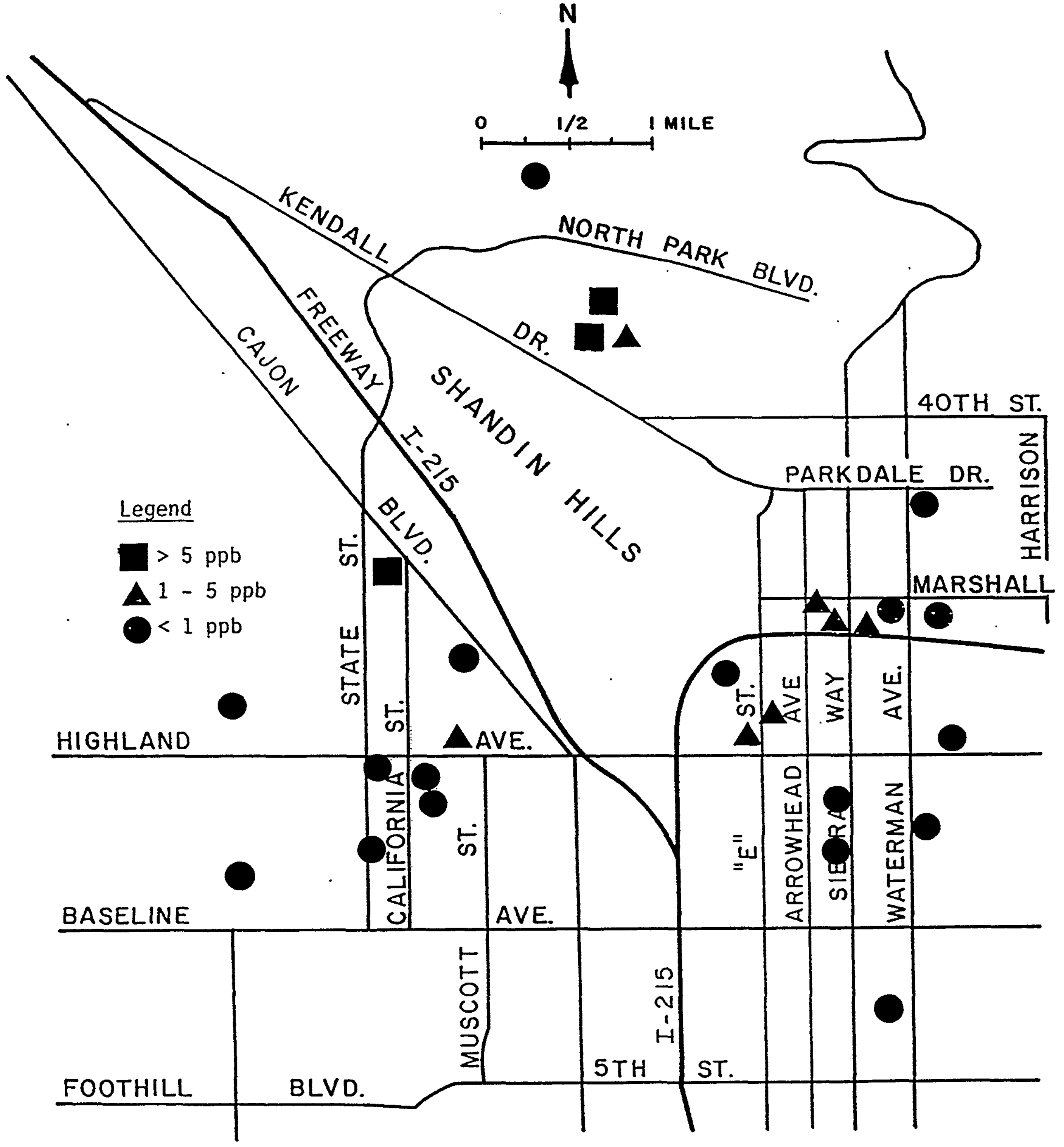
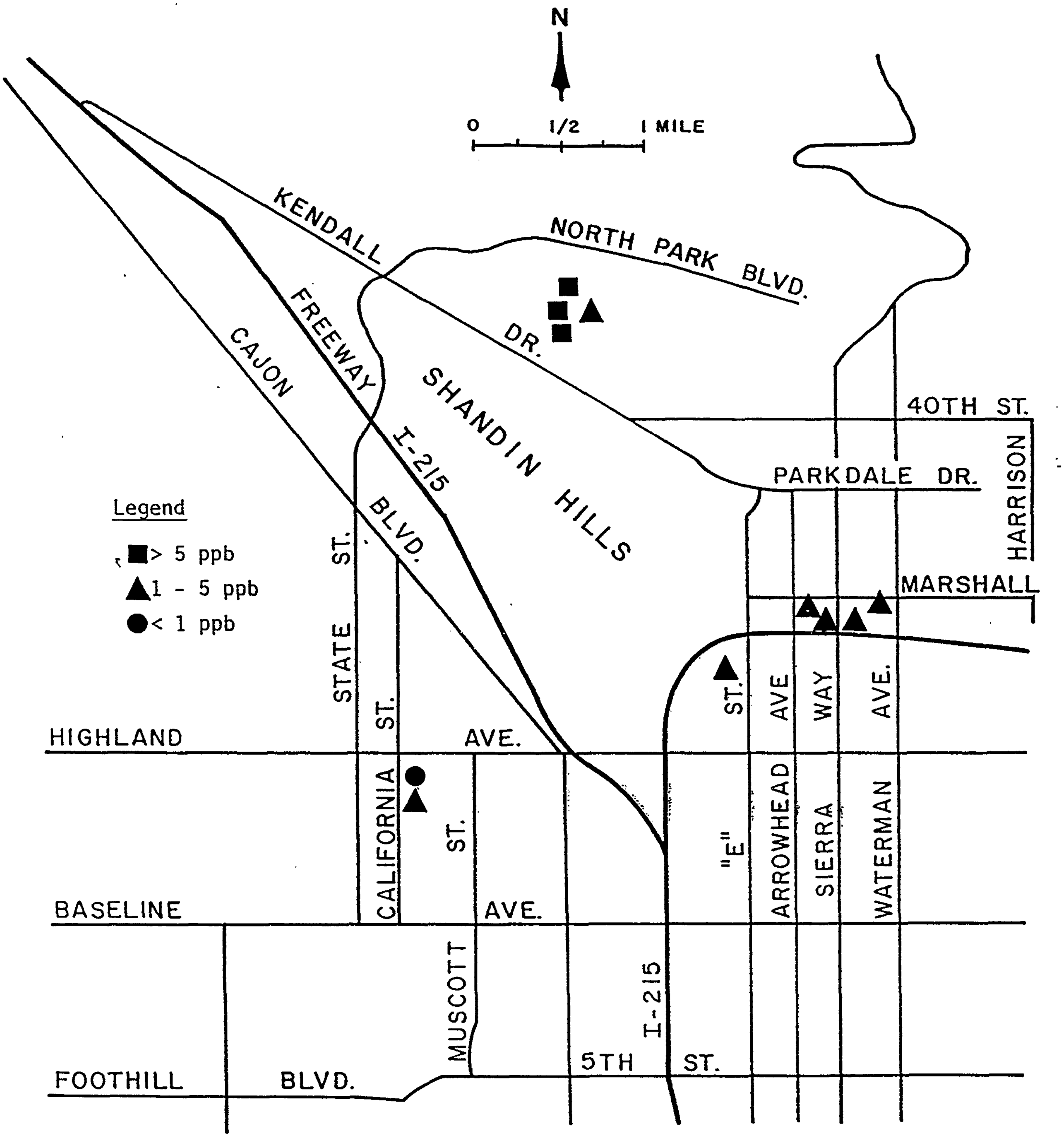
CITY00176



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 17. TCE CONCENTRATION MAP FOR THE THIRD QUARTER OF 1985



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 18. TCE CONCENTRATION MAP FOR THE FOURTH QUARTER OF 1985

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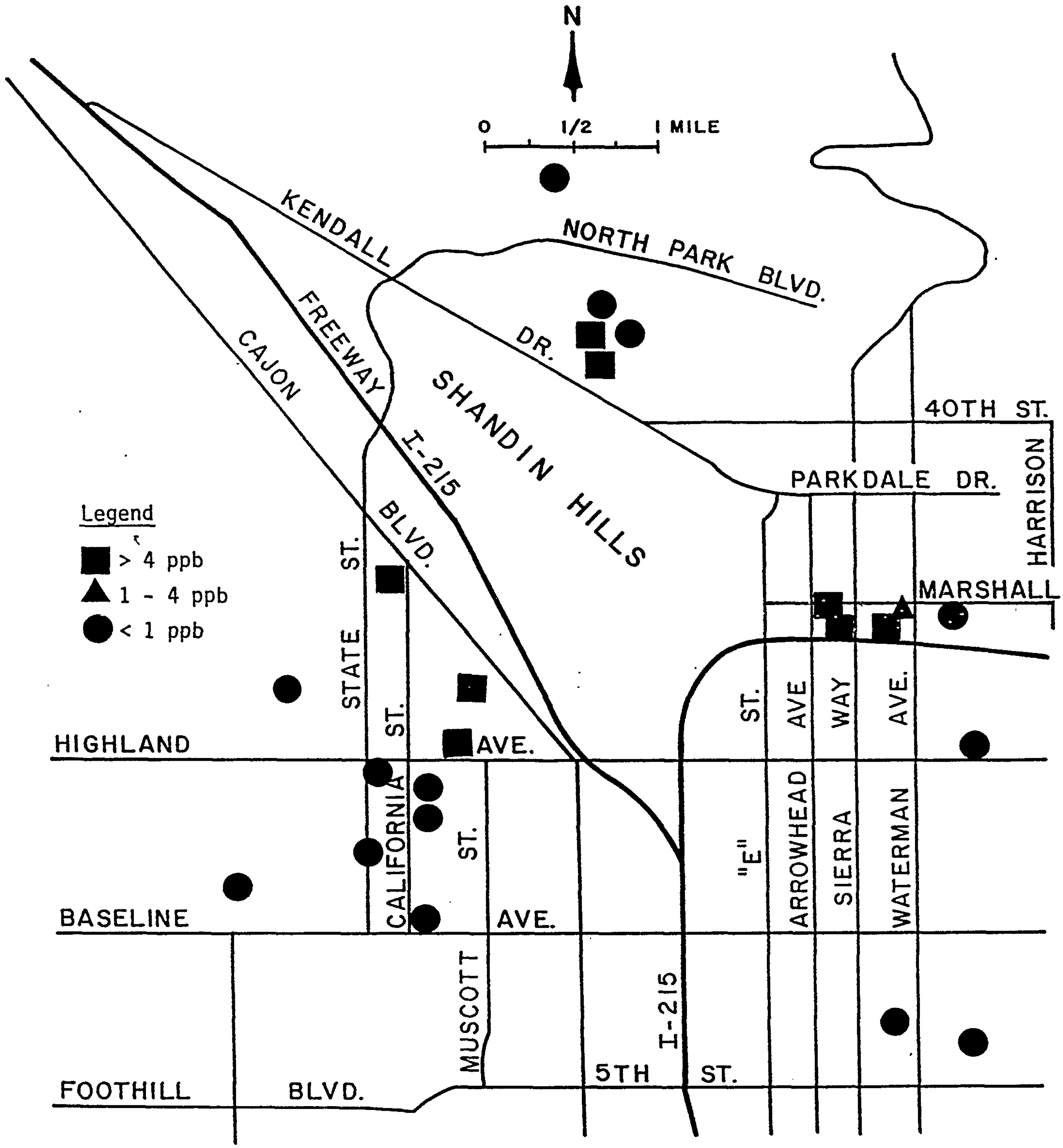

Note: See Figure 28 and Table 3 for Well Identifications.

Figure 19. PCE CONCENTRATION MAP FOR THE YEAR 1980 .

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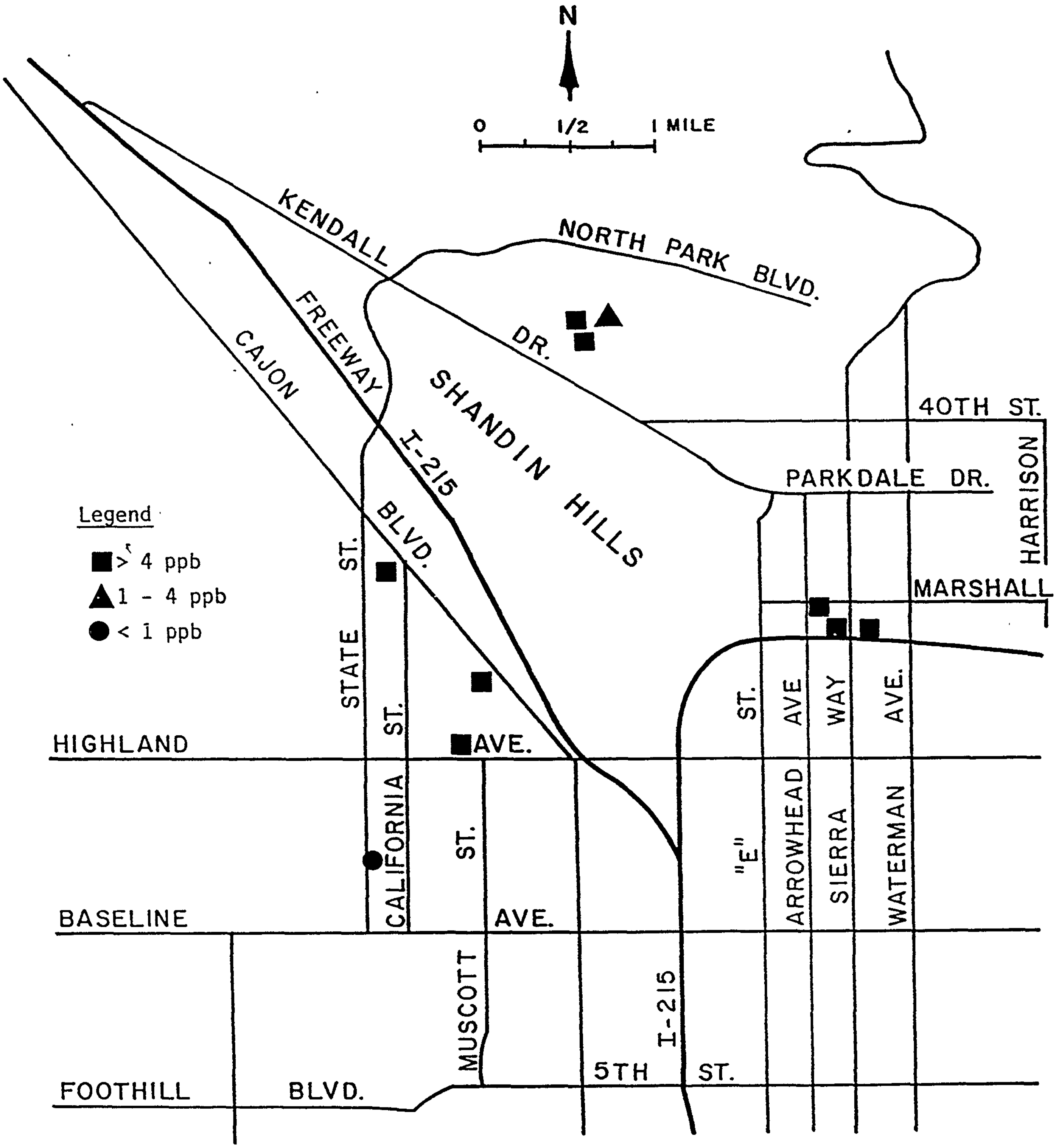
CITY00179



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 20. PCE CONCENTRATION MAP FOR THE YEAR 1981.

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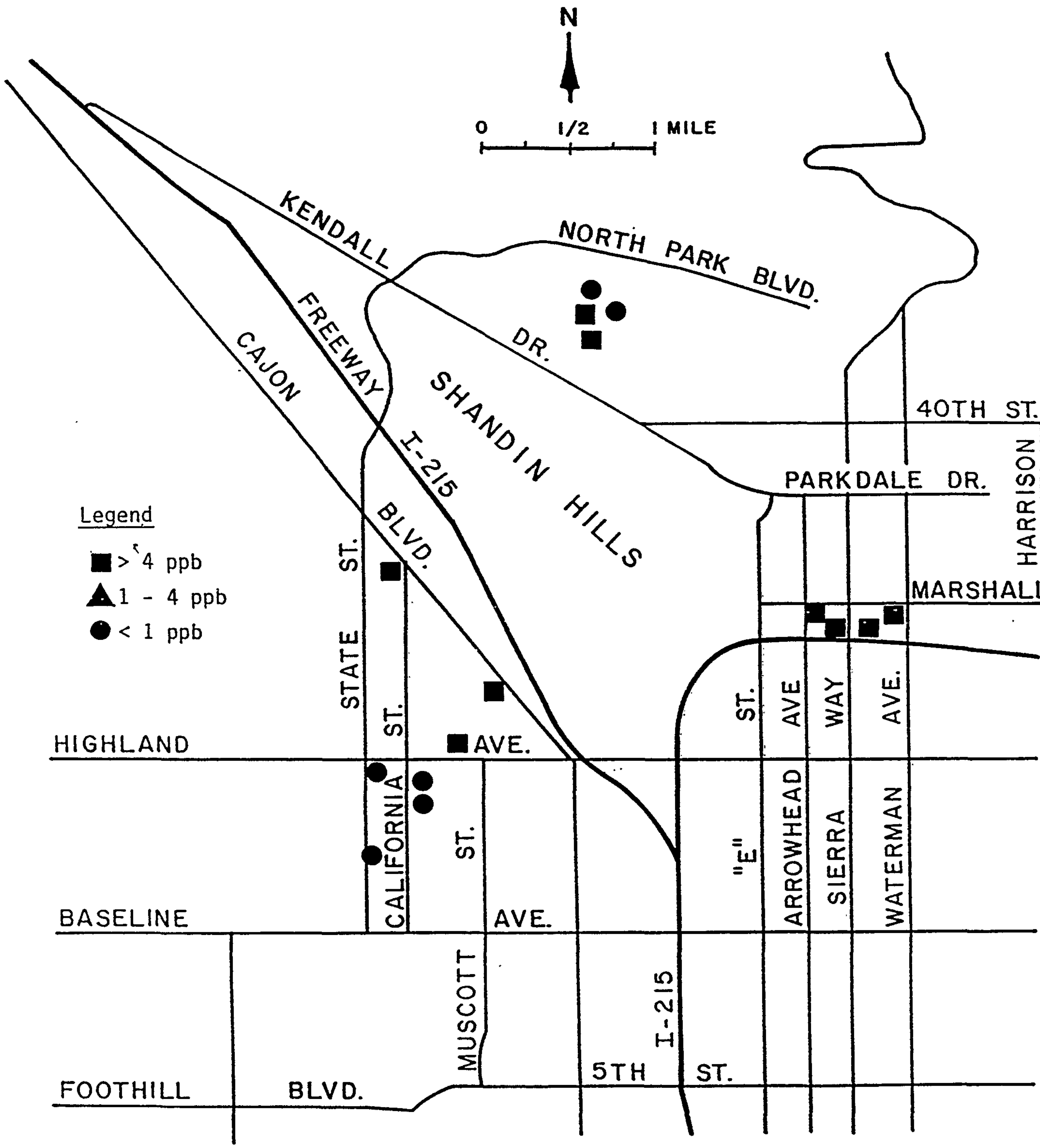
CITY00180



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 21. PCE CONCENTRATION MAP FOR THE YEAR 1982

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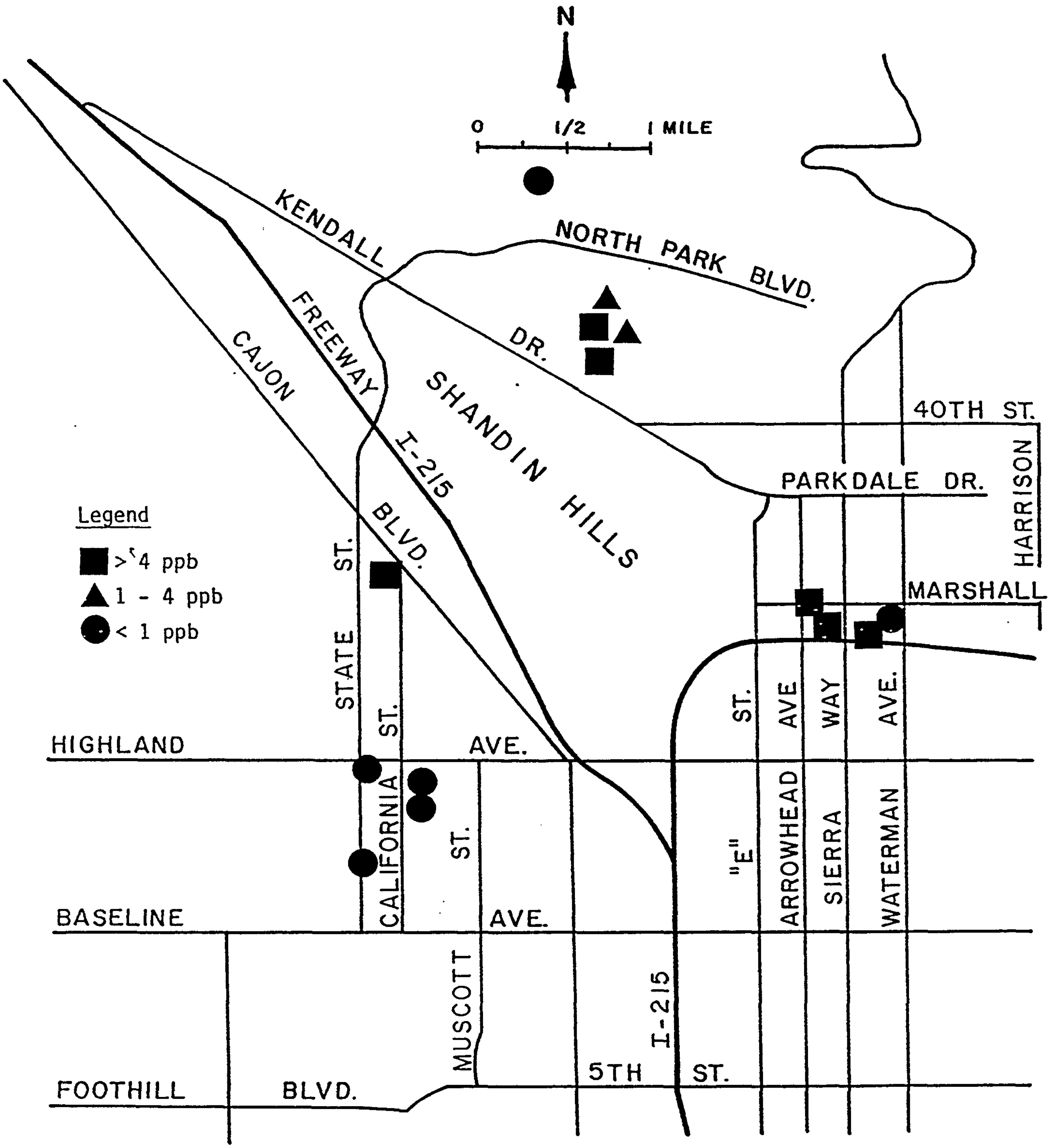
CITY00181



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 22. PCE CONCENTRATION MAP FOR THE YEAR 1983

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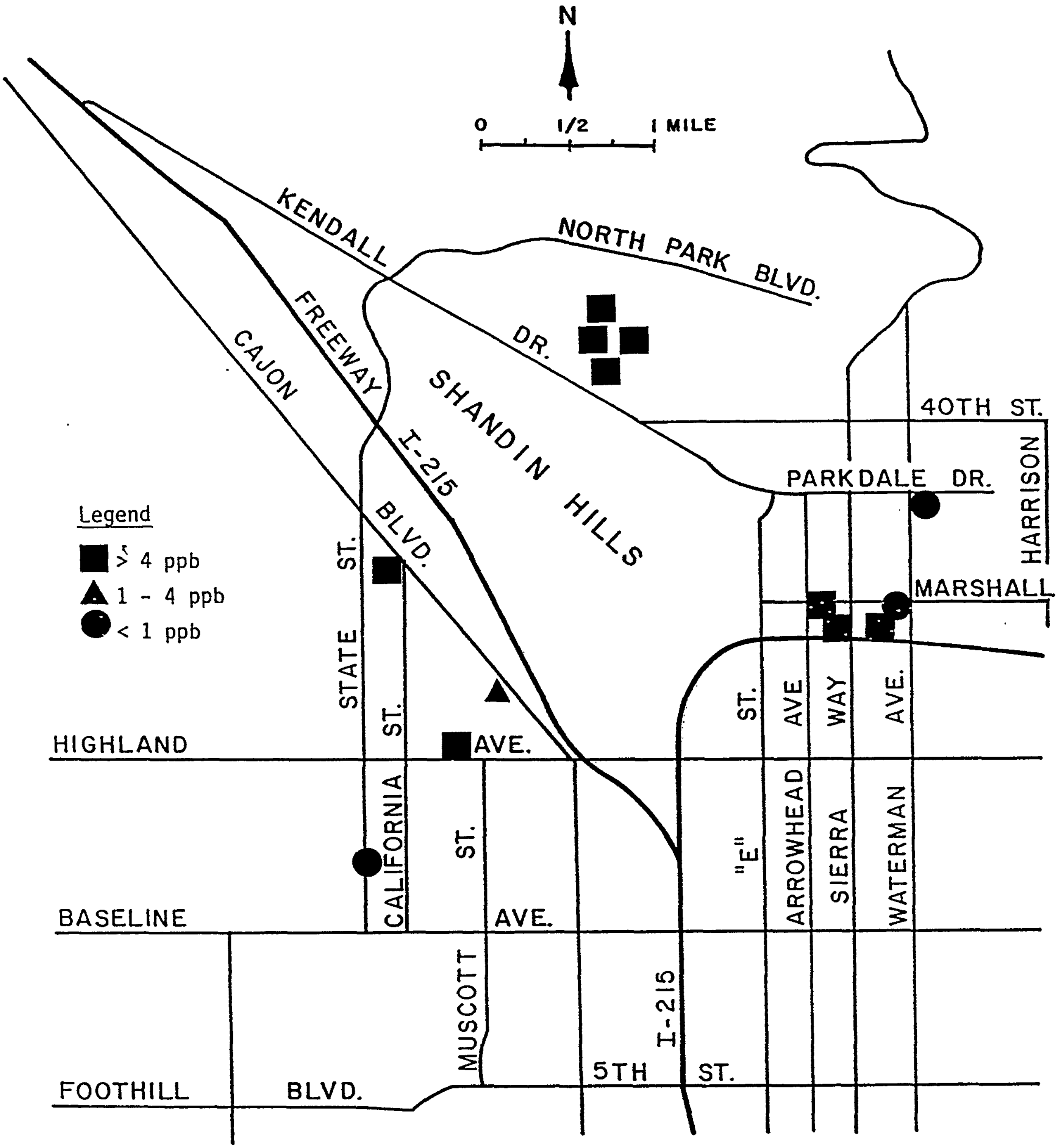
CITY00182



Note: See Figure 28 and Table 3 for Well Identifications.

Figure 23. PCE CONCENTRATION MAP FOR THE YEAR 1984.

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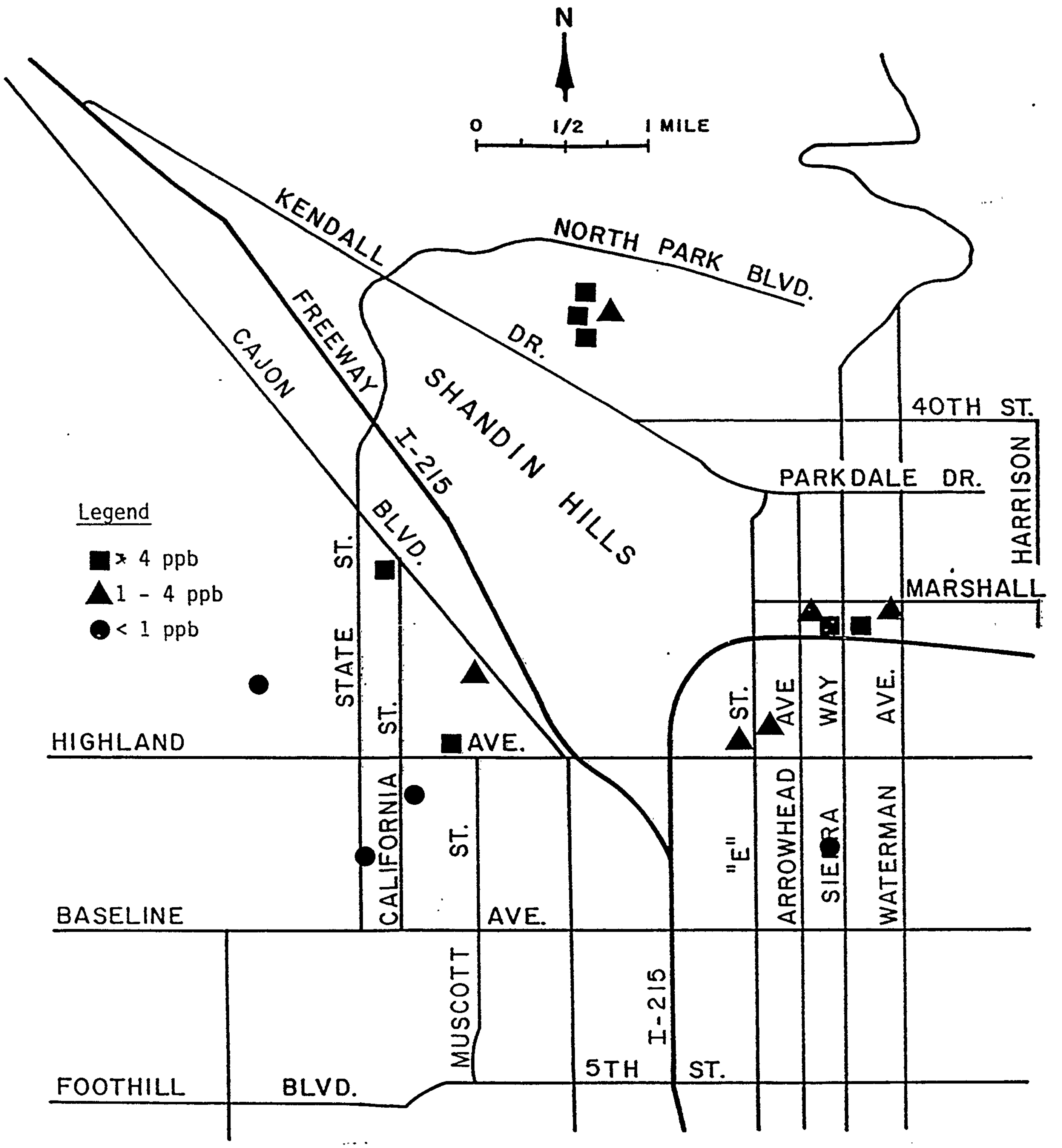
CITY00183



Note: Figure 28 and Table 3 for Well Identifications.

Figure 24. PCE CONCENTRATION MAP FOR THE FIRST QUARTER OF 1985

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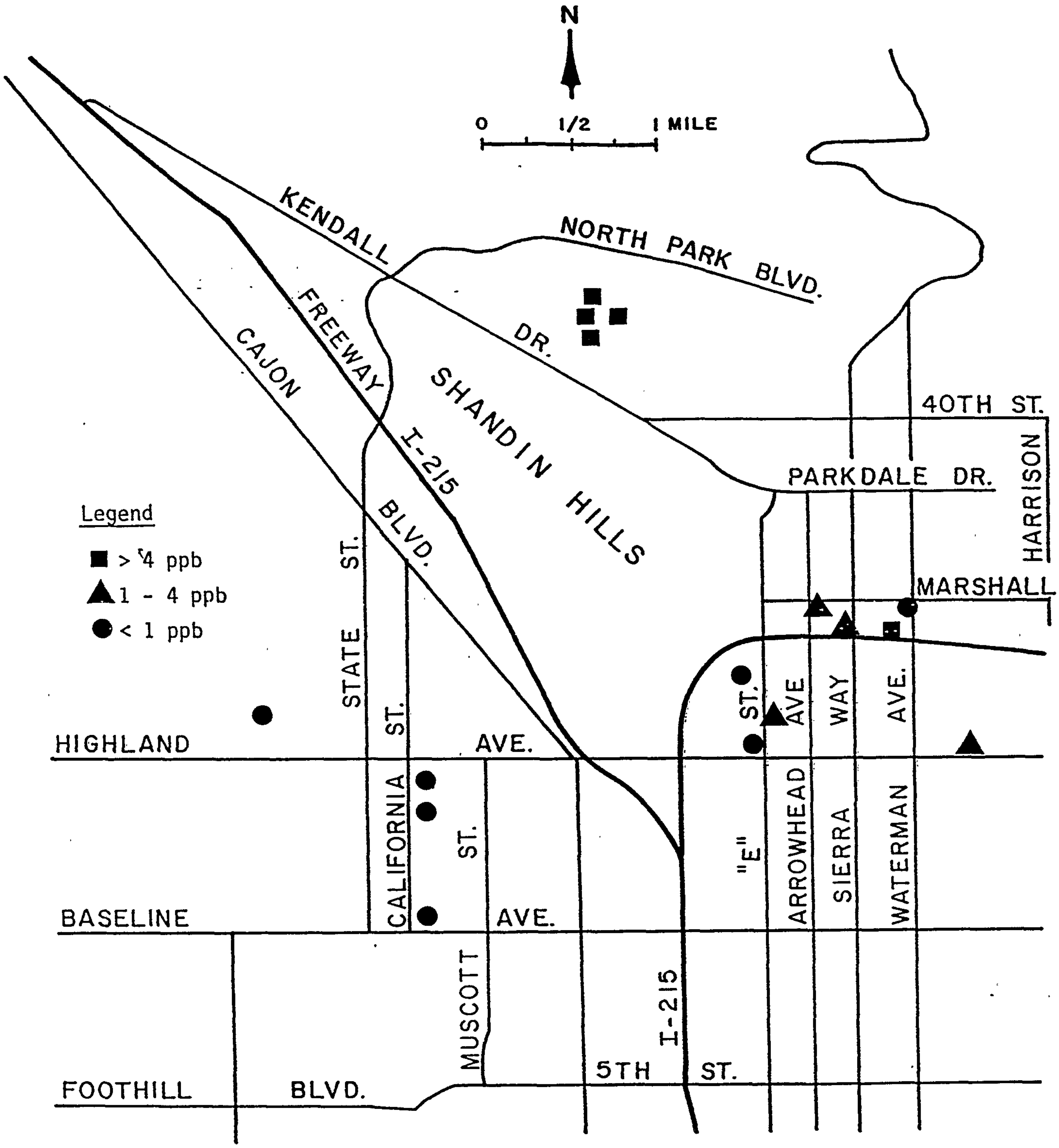

Note: See Figure 29 and Table 3 for Well Identifications.

Figure 25. PCE CONCENTRATION MAP FOR THE SECOND QUARTER OF 1985

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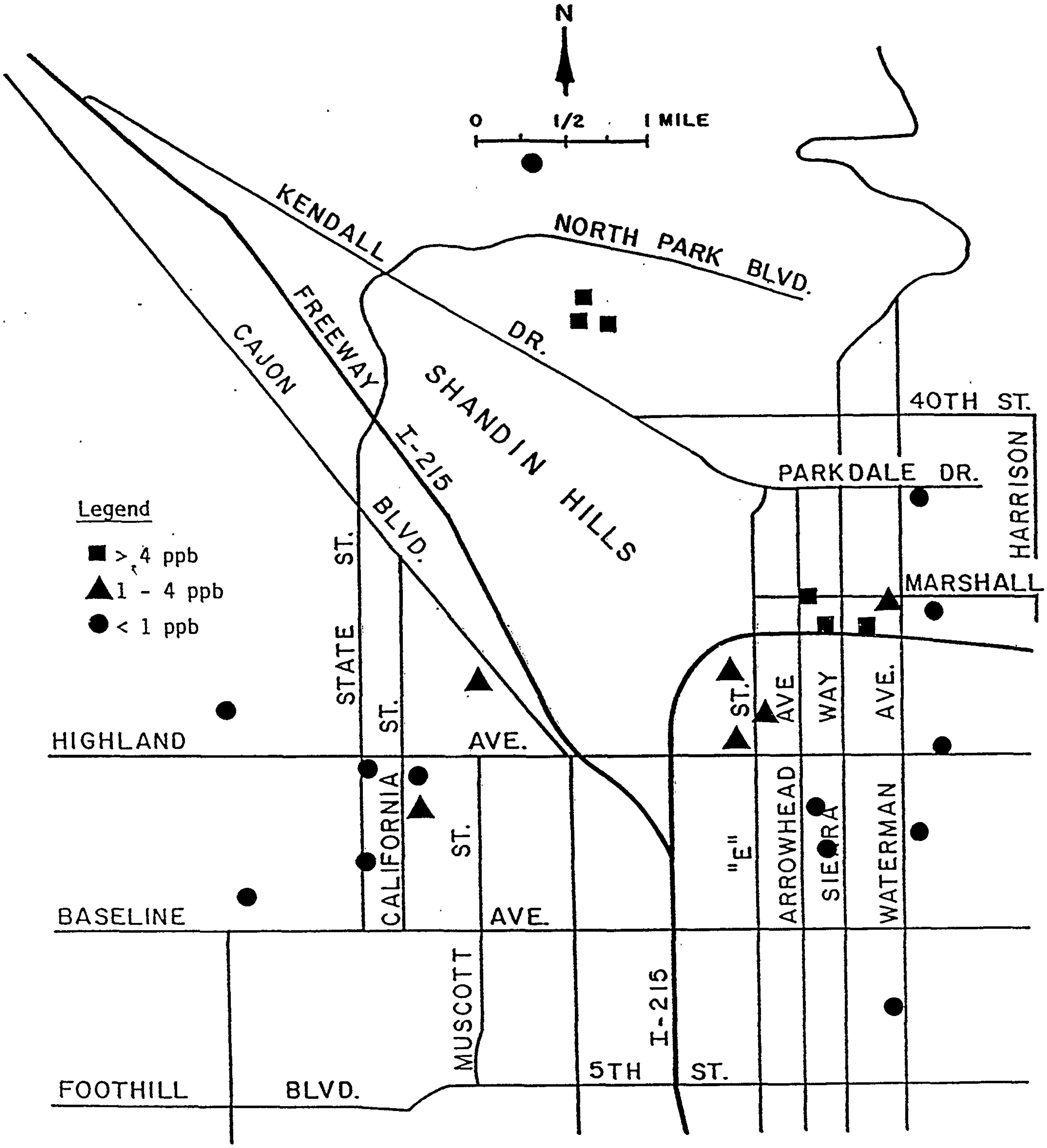

Note: See Figure 28 and Table 3 for Well Identifications.

Figure 26. PCE CONCENTRATION MAP FOR THE THIRD QUARTER OF 1985

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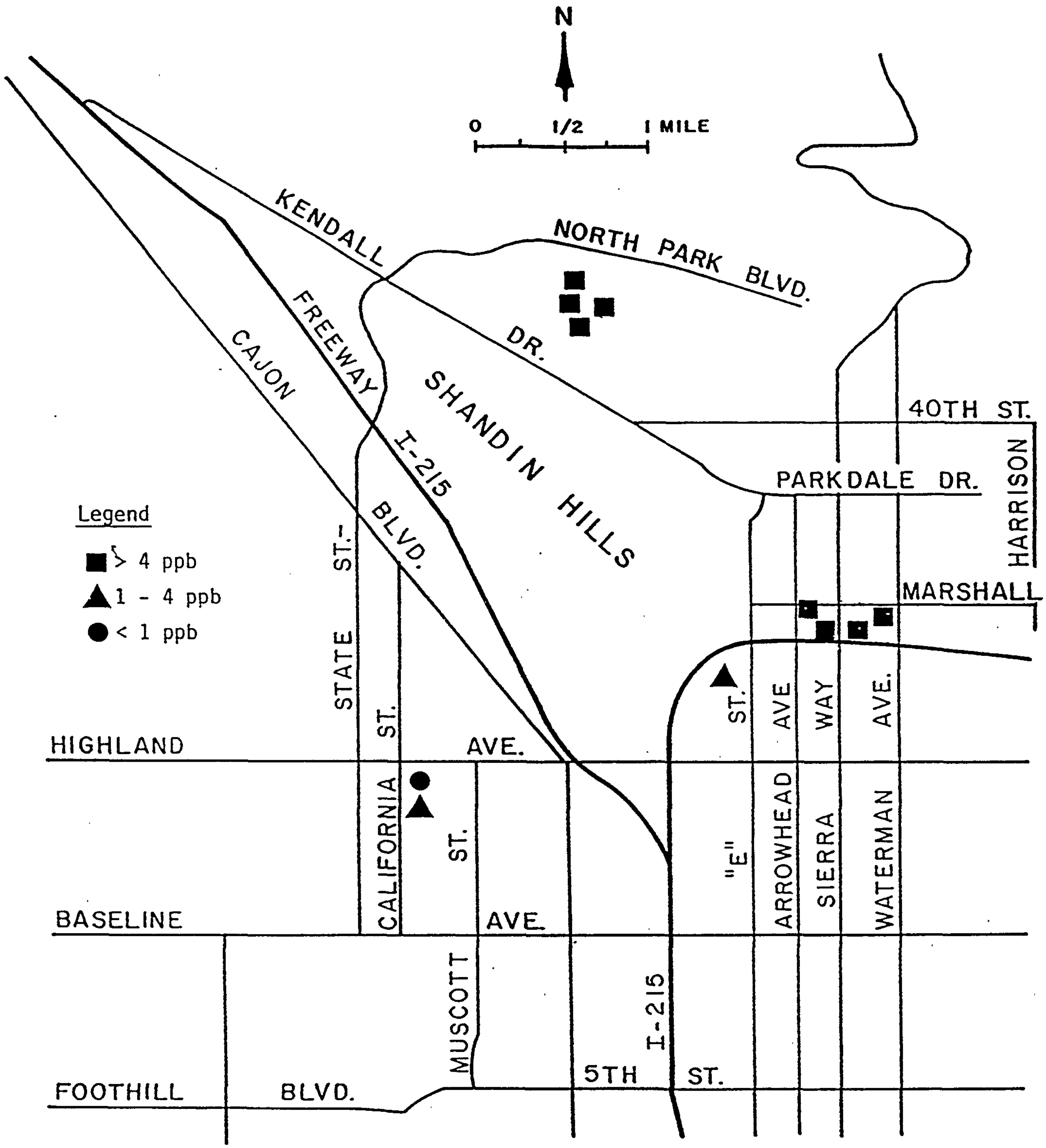

Note: See Figure 28 and Table 3 for Well Identifications.

Figure 27. PCE CONCENTRATION MAP FOR THE FOURTH QUARTER OF 1985

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Chapter 4.

AREA HYDROLOGY AND CONTAMINANT MOVEMENT

Numerous published reports exist on the geology, hydrology, groundwater conditions, and water quality in the Bunker Hill Basin. Specific detailed data about the latest directions of groundwater flow in the area of major focus of this study, however, were not directly available; and the scope of this effort did not include field work to gather such information or to corroborate the findings of previous investigators.

However, both general Bunker Hill Basin data and some now-dated specific data for the area of focus of this study were sufficient to infer approximate relationships between contaminant occurrence and hydrogeologic factors such as groundwater surface contours, aquifer characteristics, and barriers to groundwater movement.

Field studies elsewhere have demonstrated that rates of movement of organic solvents can be much lower than those of surrounding groundwaters. The degree of retardance measured in those studies appears to agree well with the theoretical construct of "retardance factors." Data on PCE retardance and values of retardance factors were available from areas geologically similar to the area of focus of this study; these are reported and used later in this chapter.

INFORMATION SOURCES

Hydrologic Reports

Hydrologic information was obtained from the reports of Mendenhall (1905) and Dutcher and Garrett (1963). The City of San Bernardino also provided data and hydrographs for selected wells. The Mendenhall hydrographs included measurements from 1892 through 1904. Dutcher and Garrett (1963) provided hydrographs and correlated groundwater level fluctuations with stream flow for the years 1931 through 1952. The well hydrographs provided by the City of San Bernardino spanned the period from 1953 through 1985. Considerable differences in recorded water levels between nearby wells have occurred, depending on proximity to other pumping wells, distances from discharge or recharge boundaries, and proximity of groundwater barriers such as faults or confining layers. Seasonal fluctuations at a single well of as much as 20 feet in the static water level elevation are common, and a decline during a drought cycle lasting 20 years can be as great as 160 feet.

Hydrogeologic Reports

Numerous hydrogeologic reports are available on various aspects of the Bunker Hill Basin. Few of these reports, however, provide detailed information on the area that is the major focus of this study. Some relevant information has been extracted from these sources, however.

Mendenhall (1905) produced one of the earliest and most complete descriptions of the original, depth, texture, and physical extent of the San Bernardino

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basin. Several cross sections and well log profiles provide a correlation of water-bearing units across the basin. The report also provided diagrams of alluvial fans and discussed examples of geologic control on infiltration of surface water into the ground which were of general interest, although later publications contained more or more up-to-date information.

More recently, Dutcher and Garrett (1963) extensively described significant geologic and hydrologic features, including numerous maps and figures showing changes in water table contours. Their report includes the following encapsulated description of the limits of the Bunker Hill Basin:

> The Bunker Hill basin is bounded on the west by the Loma Linda and San Jacinto faults and by barrier G; on the northeast by the San Bernardino Mountains; and on the south by the Crafton Hills and the badlands, where the boundary has been placed at about the contact between the older alluvium and the Tertiary to Quaternary continental deposits. The area of the basin is about 110 square miles. (p.57)

This is virtually the same area often described as the "San Bernardino Valley."

Dutcher and Garrett (1963) also placed special emphasis on quantifying the volume of groundwater outflow from the Basin across the San Jacinto Fault; between sample years 1936 and 1949, they report that discharge from the basin across the San Jacinto fault varied from 14,300 (1948) to 23,700 (1936) acre-feet per year. Their estimates of the outflow from the basin include values of transmissivity and permeability of the younger alluvium (but for areas nearer the San Jacinto Fault and outside the immediate study area).

More recent publications concerning depths to groundwater are those of Carson and Matti (1982) (for the period 1973 through 1979) and Fife et al. (1976). Fife et al. include data on depths to groundwater and the thickness of the fresh-water-bearing alluvium. These data have been used subsequently in this report to estimate groundwater flow rates.

The California Department of Water Resources (1978) quantitatively evaluated the water balance in the Bunker Hill Basin. The significant effects of an above-average precipitation year, such as 1969, in dramatically raising the regional water table are documented in that report.

A detailed investigation of aquifer characteristics in the vicinity of the Patton State Hospital (California Department of Water Resources, 1984) illustrated the great variability of transmissivity within relatively short distances. The values ranged between 100,000 and 200,000 gallons per day per foot (i.e., 13,400 to 26,800 ft^2/day) for the four wells tested. The depth of water-bearing alluvium in this area was about 600 feet, so the permeability coefficient was between 2,200 and 4,400 ft/day. Additional information in the same report (DWR 1984) on direction of groundwater flow, water quality, and temperature indicated that faults in the area may act as partial barriers to groundwater flow. Such variations in transmissivity over short distances are not unexpected, because in addition to the influence of faults as described in the above report, factors such as nearby bedrock outcroppings, sharp changes in bedrock elevation (i.e., depth of saturated aquifer), and the presence of "buried-stream" gravel beds can create similar effects.

Hardt and Hutchinson (1980) reported the development of a finite-element flow model of the Bunker Hill groundwater basin. This model includes approximately 50 elements in the main area of focus of this study and provides upper and lower aquifer transmissivity estimates for each element. These data were used, as described in subsequent sections, to calculate estimated Darcian groundwater flow velocities.

Two reports helpful to our understanding of "Fault K" behavior (see p.60 et seq.) resulted from seismologic studies associated with the installation of water transmission facilities in the north part of the San Bernardino Valley. The San Bernardino Valley Municipal Water District (1968) presented results of gravimetric traverses in the north part of the area of major focus of this study, conducted by Dr. Stephen W. Dana of the University of Redlands Geology Department. Bechtel Incorporated (1970) generally focused on the main San Andreas rift zone, but also summarized results of some seismic surveys in the Twin Creek wash area.

Warner and Moreland (1972) performed a detailed hydrogeologic study of the feasibility of artificial recharge in the Waterman Canyon -- East-of-Twin-Creek area. This work included reviews of available data, installation of test wells, and auger sampling of subsoils.

Most available reports on the geologic and hydrologic characteristics of the Bunker Hill Basin provided only general information about the region, with some selected information about the geology and hydrogeology of areas adjacent to the major area of focus of this report. No detailed hydrogeologic studies covering the study area were identified.

Mathematical Models

URS and ERM-West have each reviewed results of two modeling efforts performed in the Bunker Hill basin since 1969. The first mathematical model now belongs to the Regional Board and was developed in the 1960s by the California Department of Water Resources. It was updated with a water quality model and delivered to the Board in the late 1960s and early 1970s by Water Resources Engineers (1969). Analyses with this model have shown groundwater velocities in "nodes" (arbitrary modeling areas) near the Shandin Hills to be on the order of several hundreds to several thousands of feet per year. Velocities to the southeast in that area were computed by the model to be an order of magnitude larger than the velocities to the east-northeast. The velocity between the nodes most nearly representing the Newmark wellfield and the old airport site was modeled (in one particular case) to be 250 feet per year.

A second model reviewed was a finite-element model of the basin developed and used by the USGS (Hardt and Hutchinson, 1980). This model's nodal areas were smaller than those in the Regional Board's model and the resolution was generally finer.

Finding from these two modeling efforts are used in correlating hydrogeologic and quality data with the contaminant sources later in this chapter. While this information is useful in developing an understanding of the contaminant movement, as with the hydrogeologic reports, it must be recognized that the models reflect saturated-aquifer conditions that are generalized and regional. Application of such information to specific localized areas, such as waste disposal sites on the ground surface, at best only grossly approximates actual behavior.

Retardance Factor Data

"Retardance" (or Retardation) is a term to describe the apparent slower movement of constituents in groundwater when compared to the velocity of the groundwater itself. The retardance factor was derived algebraically in an earlier task report on this work by an engineer at ERM-West using earlier work by Weber (ca. 1975) on fluid and mass transport (in the same direction), Fickian or molecular diffusion, and the Freundlich adsorption isotherm. The resulting expression for the retardance factor was

$$R = 1 + \frac{DS}{M}$$

in which R = the dimesionless retardance factor, D = the specific gravity of the soil, S = the soil-to-water distribution coefficient of a given organic substance, and M = the volumetric soil moisture content expressed as a decimal fraction. The units are

$$D = \frac{\text{gr soil/cc soil}}{\text{gr water/cc water}}$$

$$S = \frac{\text{gr organic/gr soil}}{\text{gr organic/gr water}}$$

$$M = \frac{\text{cc water}}{\text{cc soil}}$$

Any consistent system of units could be used, but the result is that the retardation factor is a dimensionless quantity. The term is tantamount to the water's flow velocity divided by the contaminant's transport velocity. This expression results from applying conservation of mass principles to an arbitrary volume of soil. Certain simplifying assumptions are also made in the derivation, the most important of which are:

- o Adsorption of the constituent to soil is linear with respect to concentration (i.e., if the amount of constituent present in the interstitial water increases, the amount adsorbed will also increase proportionately, and the reverse linear desorption process also applies).
- o Groundwater flow and organic transport are in the same direction.
- o The constituent is not subject to transformation (e.g., hydrolysis, volatilization, or microbial degradation).

Although a number of workers have used the retardance factor concept to interpret field results, there are relatively few cases with sufficient data to determine actual field retardance factors. In a recent paper, Mackay and

Vogel (1985, in press) described three studies with direct observations of retardance factors for volatile organics. These sites were located in Borden, Ontario; along the River Aare, Switzerland; and at Gloucester, U.K. In addition, Roberts et al. (1981) presented data on predicted and observed retardance factors in a study in Palo Alto, California. Table 2 summarizes the data from these studies, including generalized information on the geologic formations. As can be seen, retardance factors for tetrachloroethylene (PCE) were found to be on the order of 4 to 5 in sand-and-gravel aquifers in two diverse places.

The Palo Alto study also provided sufficient data to allow retardance factors to be predicted with the equation given above. These predicted retardance factors are also summarized in Table 2. The generally good agreement between predicted retardance factors and the directly observed retardance factors is noteworthy.

Table 2 also indicates that, in general, retardance factors are lower in coarser, more permeable formations. Similar observations were made in actual field studies in the Palo Alto baylands, where chloroform retardance factors ranged from 2.5 to 3.8, based on observations from wells located along three radii from a well injecting water into a sand aquifer (Roberts et al., 1981). The lower retardation factor was observed in a direction where the aquifer was apparently more gravelly.

These observations are consistent with the retardance factor theory. Coarser aquifer materials normally have lower organic content and relatively less surface area. Consequently, lower retardance factors are normally expected in more coarse-grained aquifers.

The studies summarized by Mackay and Vogel (1985, in press) did not include any observed retardance factors for TCE. However, based on relative octanol-water partition coefficients and aqueous solubilities, they estimated that the retardance factor for TCE would be about one-half that for PCE.

For the area of focus of this study, the linear adsorption assumption listed earlier should be generally satisfied. The aqueous solubilities of TCE and PCE are on the order of 1,000 micromoles per liter, whereas actual concentrations in the study area are on the order of 0.01 to 1 micromole per liter, or three to five orders of magnitude below the limit of solubility. This is within a range where a linear adsorption isotherm is generally expected.

The uni-dimensional flow and organic transport constraint is similarly not restrictive. As discussed later, contaminant transport estimates were based on water surface gradients and transmissivities of specific aquifer elements. These elements are sufficiently small so that, on the scale of the overall study area and in view of the general absence of significant confining layers, flow within each element can reasonably be assumed to be one-dimensional. Also the TCE and PCE concentrations observed in the Bunker Hill Basin thus far (0-200 ug/l, usually less than 20 ug/l) are not indicative of great pools of either solvent settling vertically through a horizontally moving body of water; the solvents appear to be moving with the water if more slowly than the water.

Table 2

SUMMARY OF STUDIES WITH OBSERVED RETARDATION FACTORS

	Retardance Factors at Field Study Locations			
	Borden, Ontario	River Aare Switzerland	Palo Alto, California	Gloucester, U.K.
Characteristics	Sand	Sand and Gravel	Silty sand with some gravel	Sand and gravel with interbedded silts and clays
Chloroform	--	--	2.5-3.8 (3.0)	--
Dibromochloromethane	--	--	6 (8)	--
Bromoform	--	--	6 (10)	--
Carbon Tetrachloride	2	--	--	23
1,2-Dichloroethane	--	--	--	8
1,1,1-trichloroethane	--	--	12 (8)	--
Tetrachloroethylene	4-5	5	--	--
Benzene	--	--	--	9
Chlorbenzene	--	--	33 (17)	--
1,2-Trichlorobenzene	5-7	--	Ca. 100 (60)	--

Note: Numbers in parentheses indicate values predicted from aquifer characteristics.

Sources: Mackay and Vogel (1985, in press), and Roberts _et al_. (1981).

The chemical transformation assumption is probably the most significant. Volatilization of TCE and PCE are almost assuredly occurring in the ground, particularly in the unsaturated zone. However, the effect of chemical transformation would be to increase the apparent retardance factor (by introducing a means of removing contaminant from the water in addition to adsorption). Thus, the assumption that transformation does not occur is a "conservative" one, with respect to use of the concept for predicting travel times and travel distances (i.e., transformations actually occurring would mean travel times and distances predicted from tracer break-through data would be larger than the actual times or distances).

Significantly, the observed retardance factors summarized in Table 2 reflect field observations, not merely theoretical or only laboratory conditions.

It should also be noted that near specific sources of contamination, adsorption may be significantly nonlinear, and there may be contaminant movement in a distinctly nonaqueous phase. Also, in some areas, such as near major extraction or recharge areas, there may be significant changes over time in flow directions; and near pumping wells the transport of solvent may be increased to virtually purely advective movement (R = 1).

Finally, it should be made explicit that measurements of retardation factors in the Bunker Hill Basin were not available; we are aware of no previous work to measure them, and we were not able to perform such measurements in this study. We also were not charged with making field measurements of distribution coefficients, soil moisture contents, or soil specific gravities; nor were we able to discern from our drilling a quantitative estimate of organic contents of soils on mineralogic or soil-chemistry parameters that would demonstrate similarities or differences with the aquifer materials for which retardance factors are reported in our cited literature. We note in passing that the retardance concept has been applied often (and was derived algrebraically here) for the unsaturated-zone vertical seepage case and not for the saturated-zone transport situation. (Note that the volumetric soil moisture content, M, is nothing more than the porosity of a saturated aquifer.) It is perhaps useful to report as well that anecdotal, unpublished writings by our subcontractor who performed our soil pore gas analyses, reported later herein, reflect that retardation may be slight to nonexistent in the saturated zone compared to advective movement with the water. Moreover, dispersion or diffusion of a contaminant could conceivably be great enough that at least traces of a contaminant could appear in a downstream observation well far before the center of mass of the contaminant appears, even if retardance were actually occurring in the saturated aquifer.

Despite all these caveats about the utility of the retardance concept and its applicability in the Bunker Hill basin, the literature gives measured values for various organics in saturated aquifers at least physically similar to the Bunker Hill basin ranging from 2.5 to 100. The phenomenon fairly clearly occurs; there is no reason to suspect that it does not occur in this basin; and we have adopted and apply subsequently herein a retardation factor of 3.0 (despite the literature values of 4 to 5 for PCE) to estimate travel times of both TCE and PCE through the Bunker Hill basin.

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Water Levels

Data on groundwater levels were compiled to show historical groundwater surface elevations and gradients. The amount of available data on groundwater elevations is enormous, with observations extending to over 100 years in some areas. Wells for which water-level or geologic logs were available are listed in Table 3. Most of these are plotted in Figure 28, and the balance are plotted in Figures 29 to 31.

The City of San Bernardino Municipal Water Department maintains an extensive water level data file for many wells in the area. Since this data base provides generally ample coverage of the area of focus of this study and appears to be thorough and responsibly collected and maintained, most of the water level data used in this study were from that source. Some supplementary data were taken from Dutcher and Garrett (1963) and from records of the Southern California Water Company.

According to Dutcher and Garrett (1963), in the recharge area of the Bunker Hill basin, water levels rose approximately 40 feet in response to above-average precipitation in the late 1930s through the 1940s. (Deeper wells in the confined area of the basin -- south of this study's area of focus -- did not show a significant rise during the same period.) A seasonal fluctuation of about 20 feet, however, appears to have occurred in most years during this period.

Records compiled by the City of San Bernardino indicate steady declines in groundwater levels in the north San Bernardino area from the early 1950s through 1968. The static water level in well 1N/4W-27M01 (25th and E Street well) declined from about 116 feet below the ground in early 1953 to about 266 feet in 1967, a drop of 150 feet. A similar pattern is evident in well 1N/4W-27M02 (27th and Acacia well).

Since 1973, this decline has been reversed, with water levels rising more than 130 feet by 1982, or back to nearly the levels observed in 1953. This trend in water levels was also observed in several other city wells in this area with increases of over 100 feet having occurred in several wells between the years 1973 to 1983.

This fairly recent rise in water levels could be contributing to the observed TCE and PCE contamination patterns observed since 1980. If contaminants leaked earlier through several hundred feet of soil to groundwater, some contaminants would likely have remained adsorbed or attached to soils in the unsaturated zone. Subsequent rises in the water table would then have resulted in increased contact of groundwater with contaminated soils. At the same time, the rising water levels could also help dilute contaminant concentrations.

To aid in evaluating groundwater flow directions and velocities, Figures 29 through 31 present contours of groundwater level elevations for the fall seasons of 1965, 1975, and 1985 for selected wells in the study area. These years were selected for the following reasons:

- o Water level data were generally available for many wells for these years.

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Table 3.

WELL IDENTIFICATION INDEX

No.	Local Designation	Owner's Name	State Well No.	DWR "E"-No.
Municipal Wells (See Figure 28)				
1.	Antil #6	San Bernardino City	01S04W02K08S	
2.	Arrowhead No. 1	Arrowhead Co. Club	01N04W23E00S	
3.	Baseline & California	San Bernardino City	01N04W32N01S	E-6W
4.	Colima Well	So. Cal. Water Co.	01N04W29F01S	
5.	Darby Well	So. Cal. Water Co.	01N04W29E01S	
6.	Ellena Brothers Well	San Bernardino City	01N04W08P01S	E-9
7.	Gardena Well	So. Cal. Water Co.	01N04W29N02S	
8.	Gilbert	San Bernardino City	01N04W35M03S	E-40i
9.	Leroy	San Bernardino City	01N04W27A02S	E-435a
10.	Lynwood	San Bernardino City	01N04W26E02S	E-35z
11.	Lytle Creek No. 3	San Bernardino City	01N05W36R01S	E-6
12.	Mallory Well	S.B. Water Util. Corp.	01N04W30L000	
13.	Mount Vernon	San Bernardino City	01N04W31A01S	E-5c
14.	Newmark No. 1	San Bernardino City	01N04W16E01S	E-10
15.	Newmark No. 2	San Bernardino City	01N04W16E02S	E-10b
16.	Newmark No. 3	San Bernardino City	01N04W16E03S	E-10c
17.	Newmark No. 4	San Bernardino City	01N04W16E04S	E-10e
18.	Perris Hill No. 5	San Bernardino City	01N04W26P03S	E-3br
19.	State Well	So. Cal. Water Co.	01N04w31H01S	
20.	Waterman Avenue	San Bernardino City	01N04W27A01S	E-35w
21.	7th Street	San Bernardino City	01S04W03J000	E-0032t
22.	16th & Sierra Way	San Bennardino City	01N04W34G03S	E-31f
23.	17th & Sierra Way	San Bernardino City	01N04W34G01S	E-31e
24.	19th No. 1	San Bernardino City	01N04W32D03S	E-12j
25.	19th No. 2	San Bernardino City	01N04W32D04S	E-12k
26.	23rd & N. "E" Street	San Bernardino City	01N04W27N01S	E-26k
27.	25th & N. "E" Street	San Bernardino City	01N04W27M01S	E-26j
28.	27th & Acacia	San Bernardino City	01N04W27M02S	E-25k
29.	30th & Mountain View	San Bernardino City	01N04W27G01S	E-25q
30.	31st & Mountain View	San Bernardino City	01N04W27B000	E-251
Additional Wells (See Figures 29, 30, and 31 later herein)				
31.	Devil Canyon No. 4	San Bernardino City	01N04W06H01S	E-1
32.	Devil Canyon No. 2	San Bernardino City	01N04W07F01S	E-2
33.	Devil Canyon No. 1	San Bernardino City	01N04W08M01S	E-2a
34.	Water Exploration, Inc.	Water Explor., Inc. (Orig.)	01N04W21B02S	E-10d
35.	Well No. 3	Thomas Clapp (Orig.)	01N04W14R08S	E-34a
36.	New Well	San Bern. Country Club	01N04W23M01S	E-35t
37.	Cox Well	Roy Cox (Orig.)	01N04W24P02S	E-12f
38.	Margulas Well	W.R. Severance (Orig.)	01N04W23K01S	E-35m
39.	Paperboard Co. Well	Paperboard Co. (Orig.)	01N04W20N01S	E-4d

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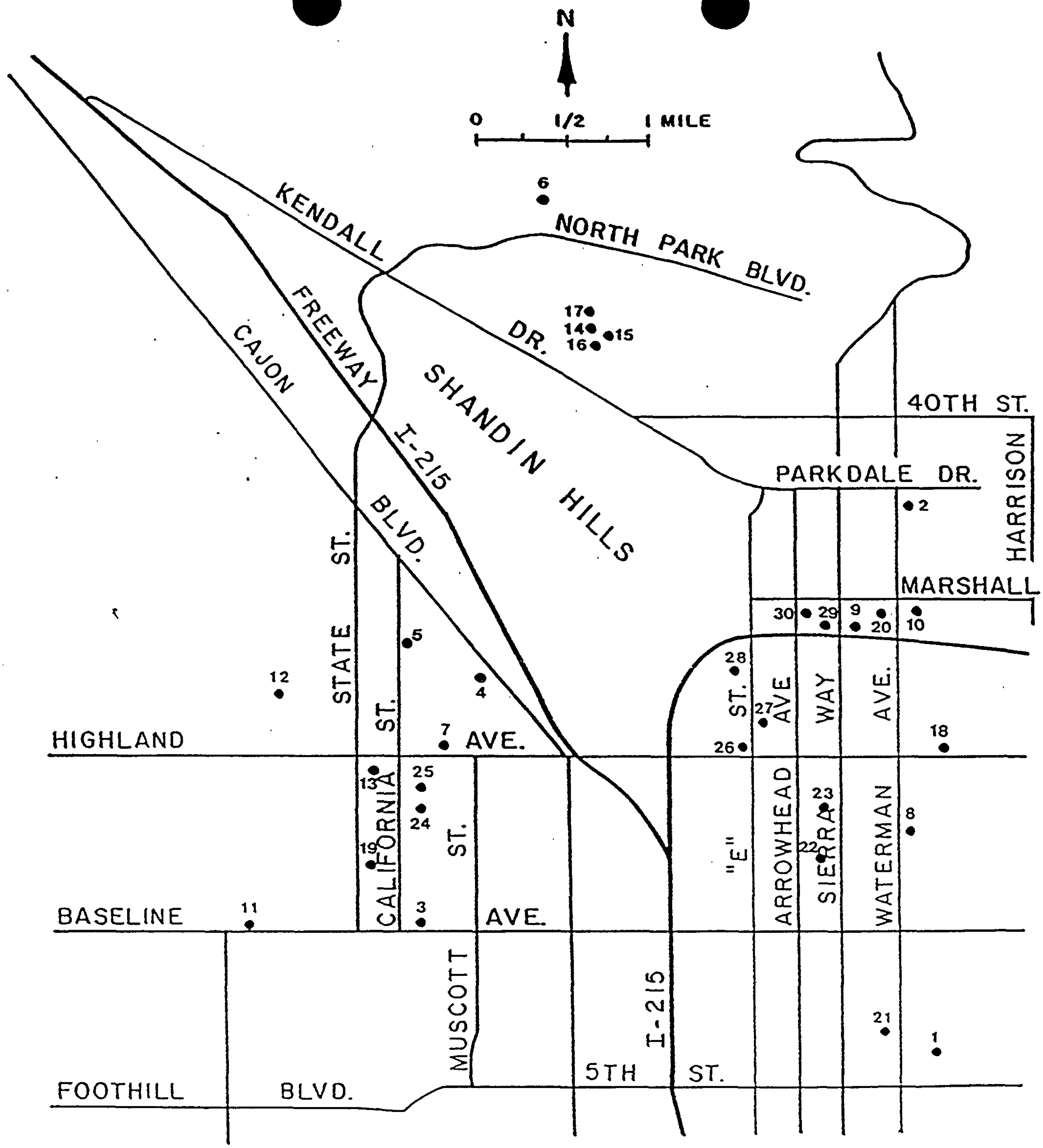

Closed Wells: (4) Colima, (5) Darby, (7) Gardena, (9) Leroy, (14) Newmark #1, (15) Newmark #2, (16) Newmark #3, (17) Newmark #4, (20) Waterman, (26) 23rd and N. "E" Street, (27) 25th and N. "E" Street, (28) 27th and Acacia; (29) 30th and Mt. View, and (30) 31st and Mt. View

Figure 28. LOCATIONS OF INDEXED MUNICIPAL WELLS LISTED IN TABLE 3

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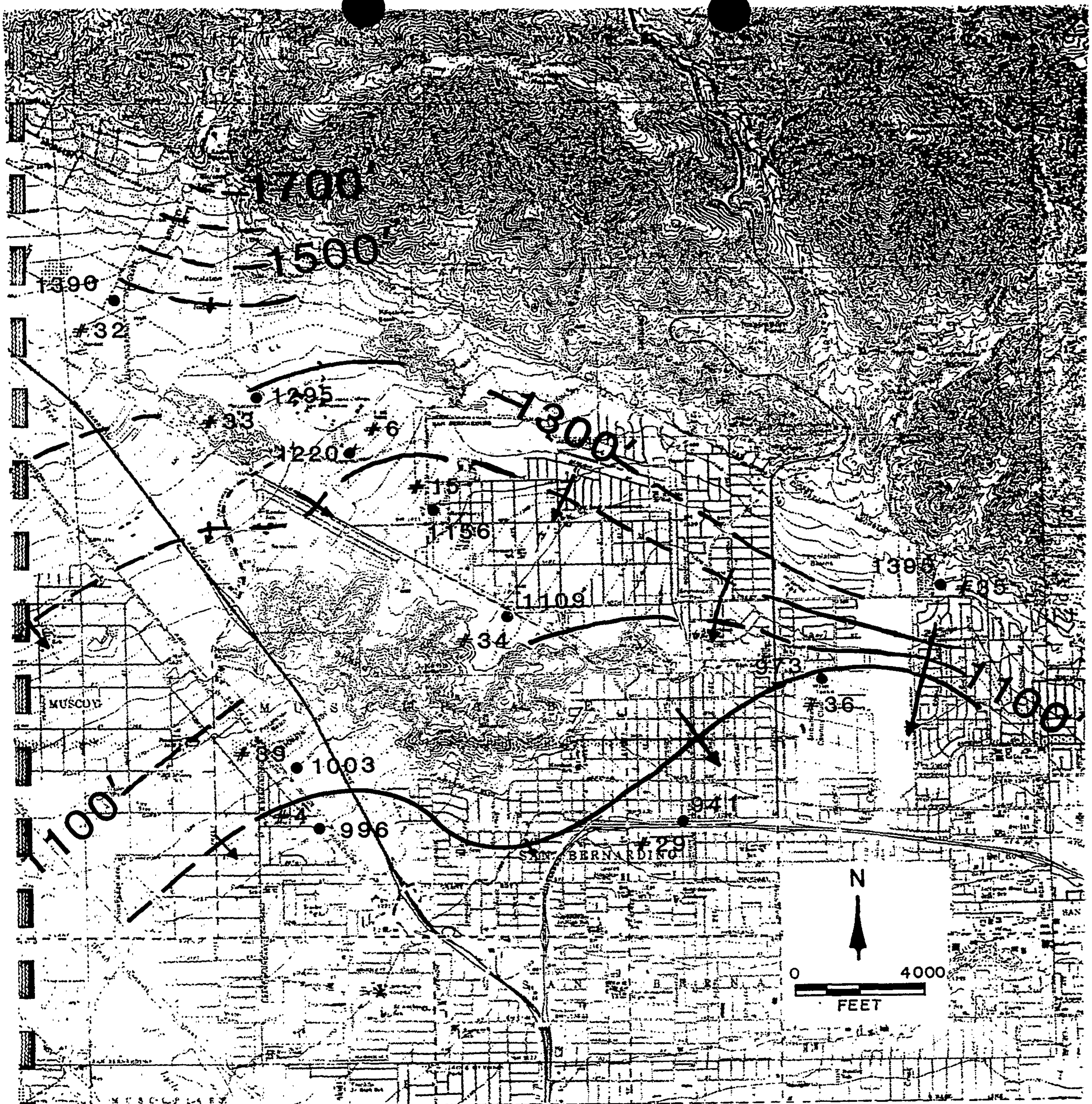

Note: See Table 3 for identification data for these wells.

Lengths of arrows are proportional to velocity.

Figure 29. FALL 1965 WATER LEVEL CONTOURS AND FLOW DIRECTIONS

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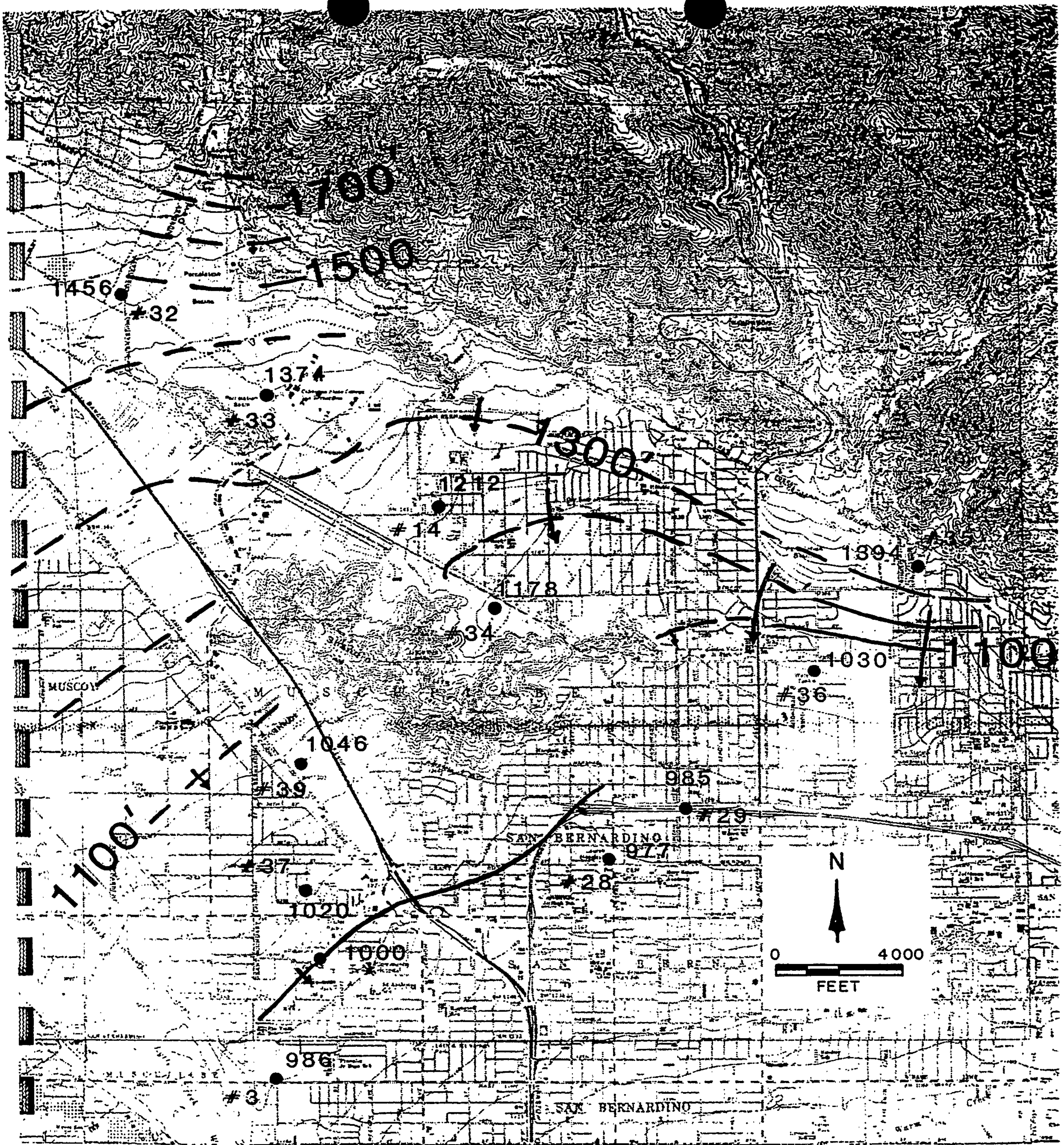
CITY00198



Note: See Table 3 for identification data for these wells.

Lengths of arrows are proportional to velocity.

Figure 30. FALL 1975 WATER LEVEL CONTOURS AND FLOW DIRECTIONS

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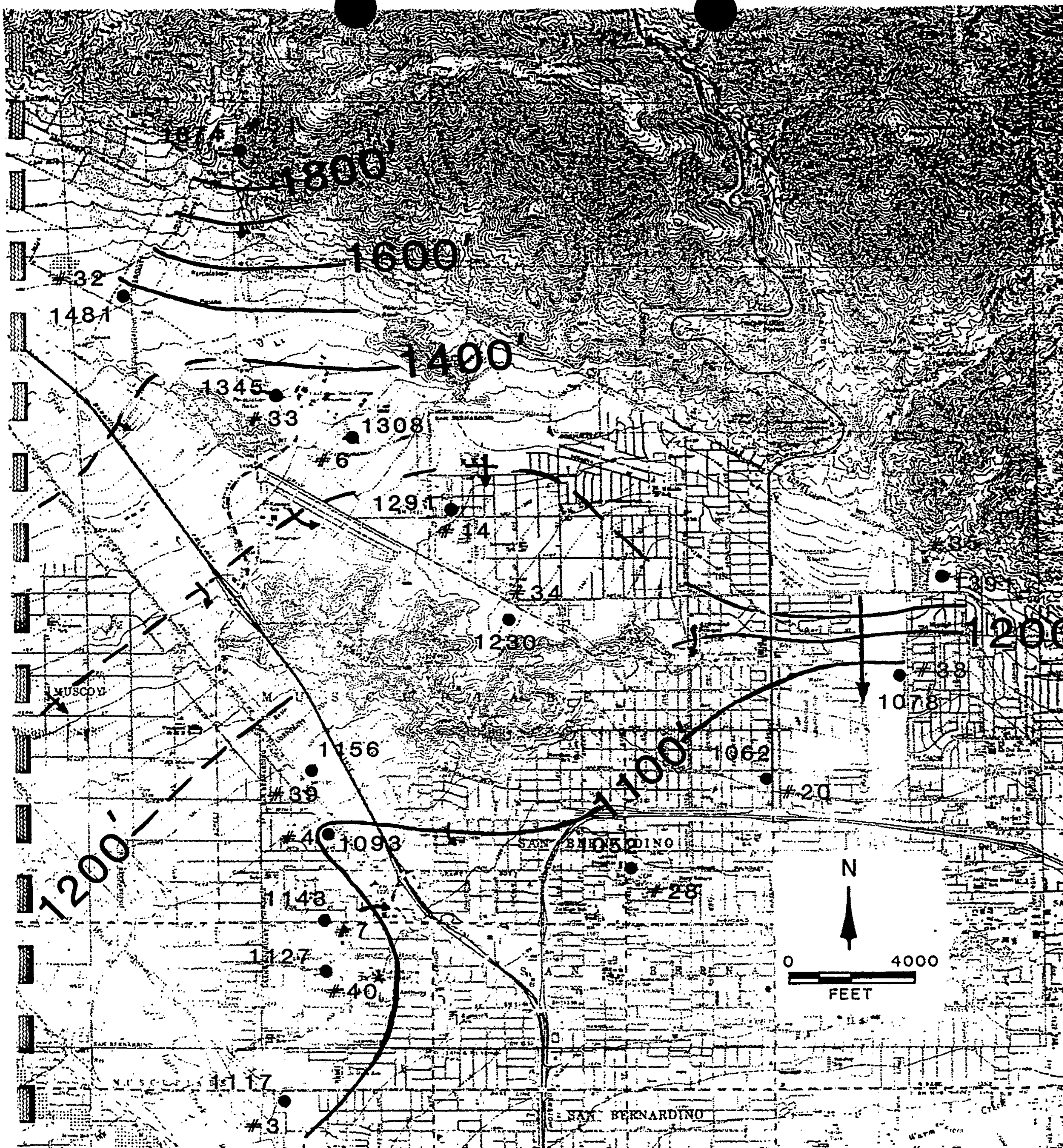
CITY00199



Note: See Table 3 for identification data for these wells.

Lengths of arrows are proportional to velocity.

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Figure 31. FALL 1985 GROUNDWATER ELEVATIONS AND FLOW DIRECTIONS

CITY00200

- The years 1965, 1975, and 1985 bracket a period of major change in groundwater conditions, i.e., the reversal of and substantial recovery from the post-World War II decline in groundwater levels.

Fall season data only were selected for display here because they were substantially the same as spring season data for the same years, which were also available.

These water level maps illustrate that recovery of ground water levels of 100 feet between 1965 and 1985 are common throughout much of the area. At the same time, water surface elevations in the upper end of Twin Creek wash are shown to have stayed relatively constant, resulting in some flattening of the groundwater surface profile (slowing of water movement in response to gradients) in the area north-northeast of the Shandin Hills, particularly between 1975 and 1985.

AQUIFER CHARACTERISTICS

Alluvial deposits in the Bunker Hill Basin were derived primarily from the surrounding San Gabriel and San Bernardino Mountains. The alluvial valley fill deposits have been transported, sorted and deposited in layers to fill the wedge-shaped basin formed between the San Andreas and San Jacinto faults. The materials are somewhat coarser near their sources along the base of the mountains. The formations tend to grade to finer sizes as a function of distance carried from the original source. Deposits to the south, near the basin boundary created by the San Jacinto fault, are somewhat finer-grained and interlayered with more clay lenses.

The water-bearing units that are the subject of this study include the upper and middle water-bearing units identified by Dutcher and Garrett (1963). Because previous reports have not described in detail the geology of the main area of focus for this study, three geologic cross-sections were prepared from available well logs in the area to provide an indication of the depth and thickness of the water-bearing units in the study area. Figure 32 shows these sections as well as the locations of selected faults.

Cross-section A-A', Figure 33, illustrates formations in the vicinity of the Newmark wells north of the Shandin Hills. This section also closely parallels Fault K. As Figure 33 indicates, these materials are predominantly sand and gravel, with relatively few clay layers or lenses. The overall lithology indicated by Section A-A' is quite uniform. The aquifer materials also appear to become finer in an easterly direction along this section.

Cross-section B-B', Figure 34, parallels Section A-A', generally about 2 miles to the south. This section illustrates the changes in texture that occur from the basin edge near Muscoy to the deep, central portions of the Basin. In the Muscoy area, the deposits appear to consist almost exclusively of sands and gravels, presumably reflecting deposits of coarse materials associated with Cajon Wash. To the east, the deposits appear to be finer, showing increasingly complex stratigraphy. The water-bearing units represented in this cross section are the upper and middle units referred to by Dutcher and Garrett (1963).

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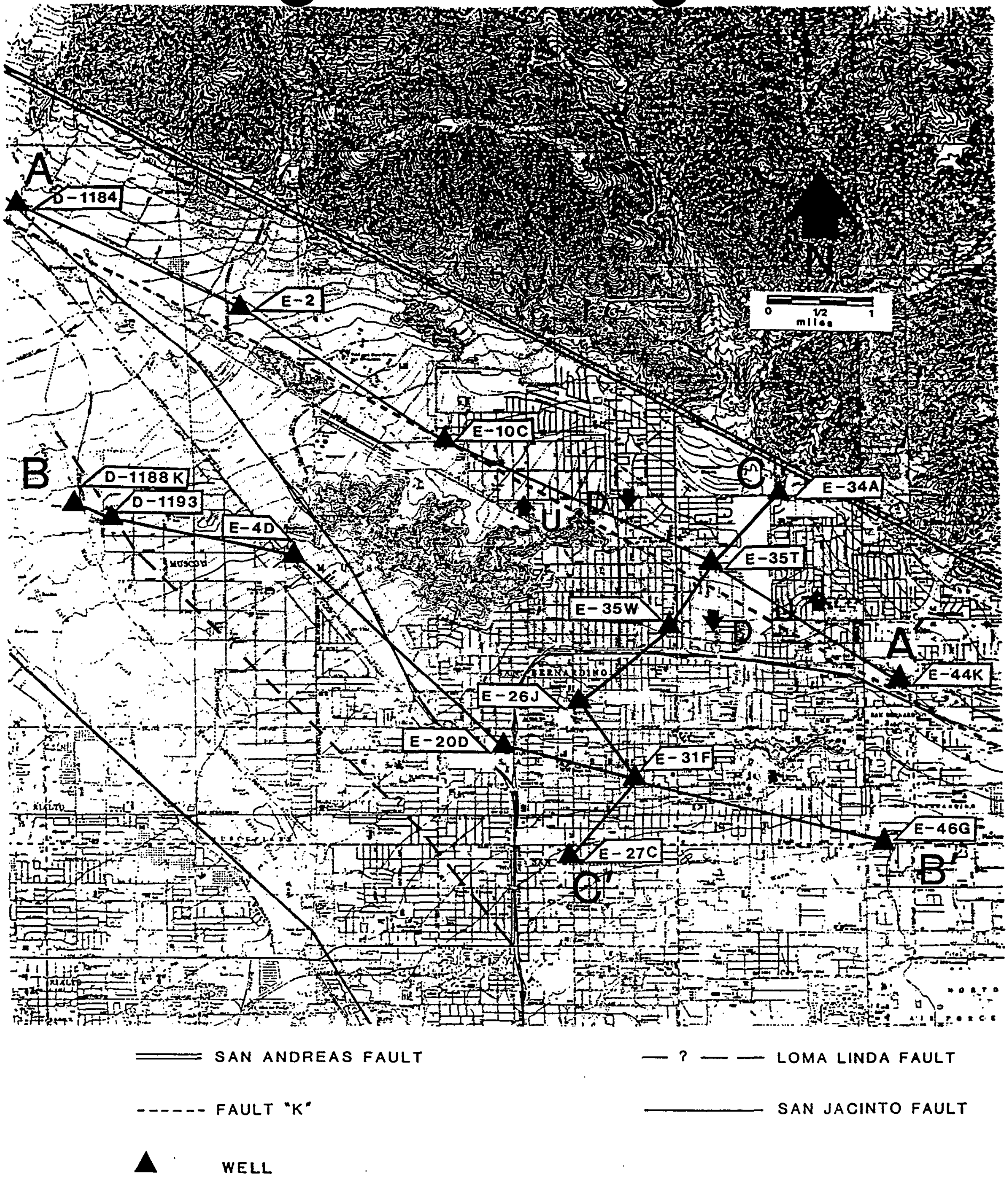

Figure 32. LOCATIONS OF FAULTS AND THIS REPORT'S CROSS-SECTIONS

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CITY00202

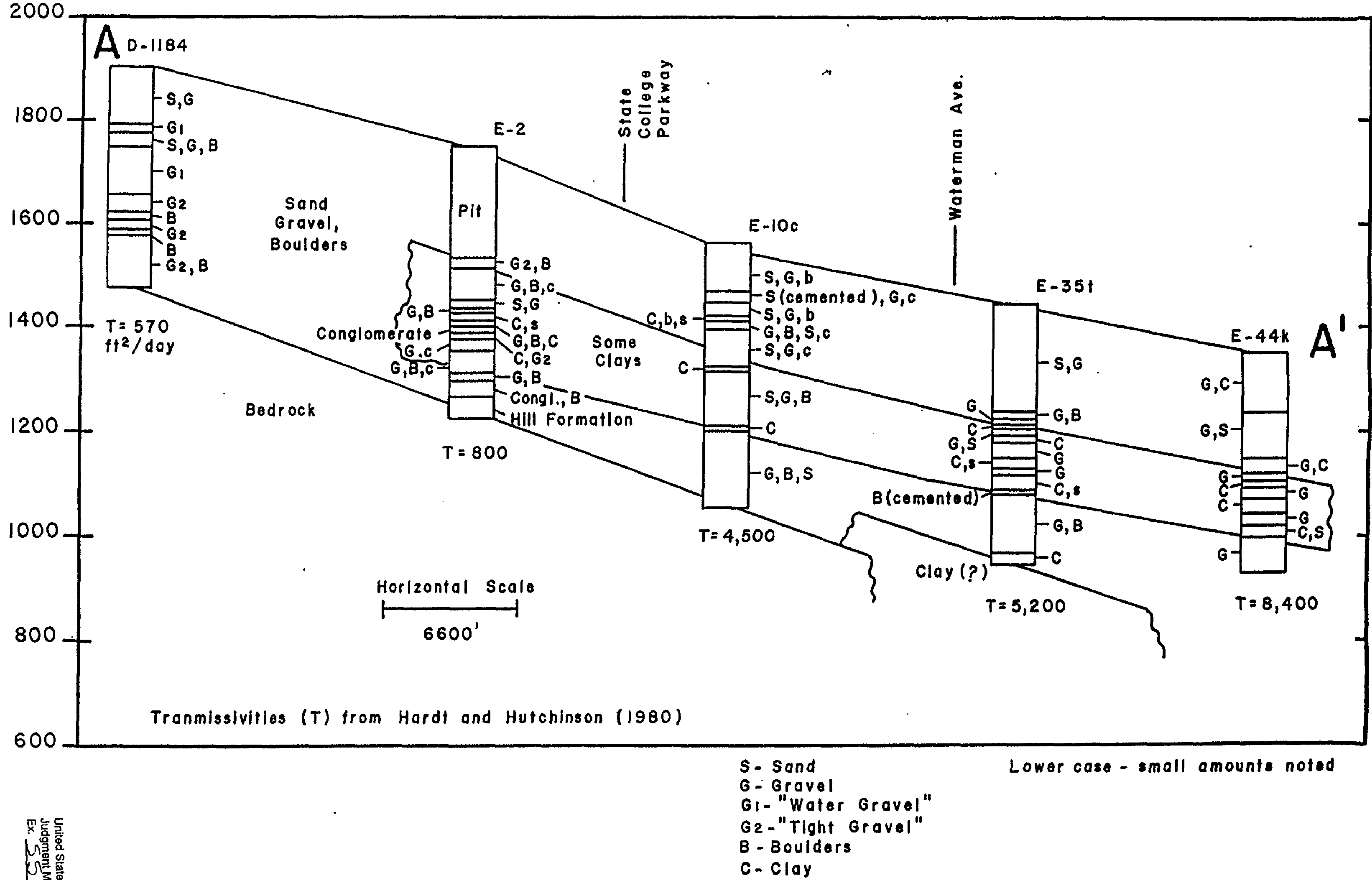

Figure 33. GEOLOGIC SECTION A-A'

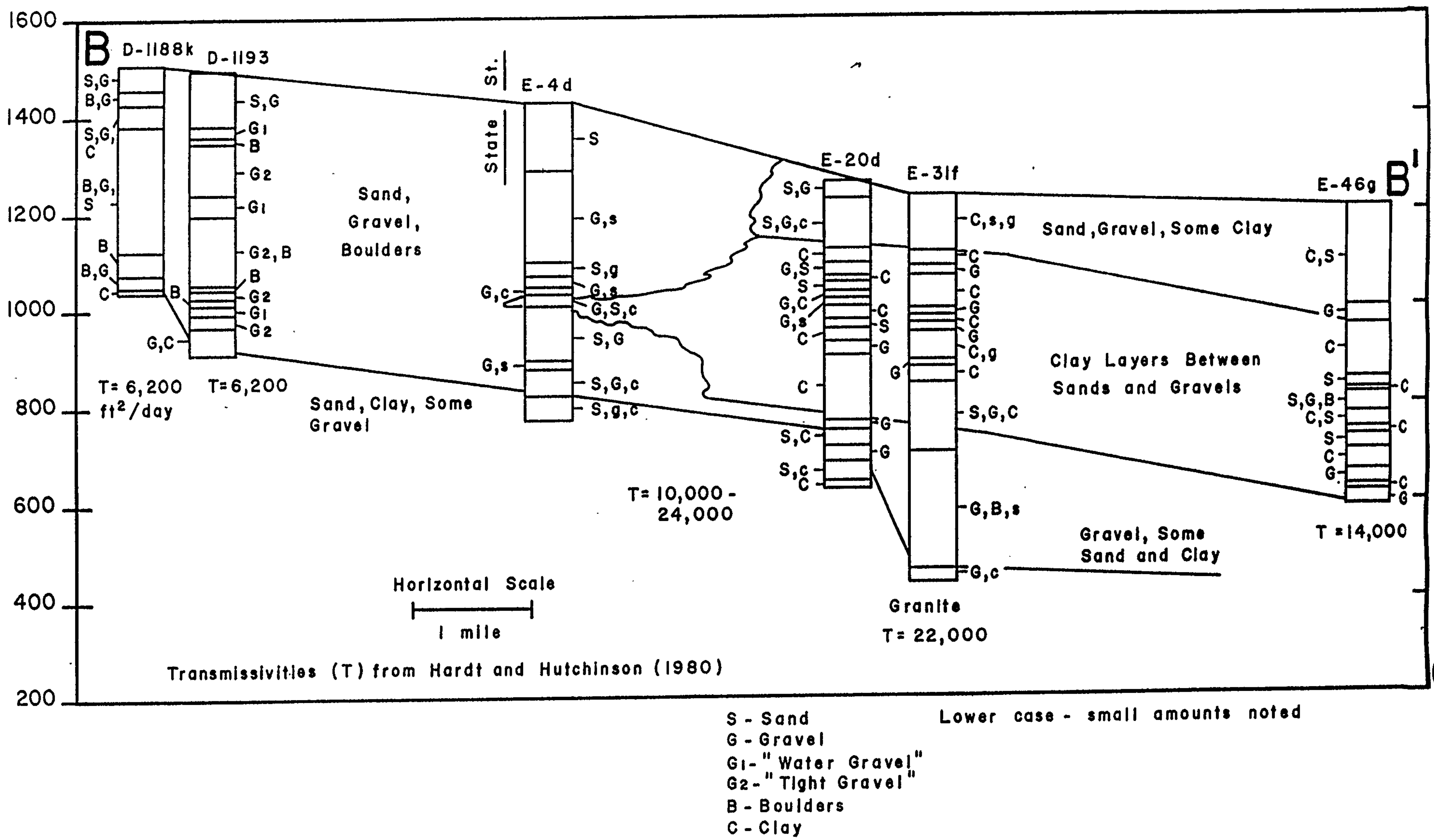

Figure 34. GEOLOGIC SECTION B-B'

Section C-C', Figure 35, is oriented primarily in a NNE to SSW direction, crossing Sections A-A' and B-B' nearly perpendicularly. This section illustrates the grading and sorting of aquifer materials from coarse materials near the mouths of streams to finer materials toward the center of the Basin. The southerly end of Section C-C', which extends into the confined (pressure) zone portion of the Basin, exhibits quite complex stratigraphy. Where Section C-C' crosses Fault K, the relative movement is indicated as away (A) and toward (T) the reader.

Based on the findings of potential source locations, primary areas of potential sources of contamination are in the Muscoy and Delmann Heights areas and in northern San Bernardino, north of Highland Avenue. The geologic cross-sections indicate that in these areas the aquifers are largely uniform and without major confining members or extensive deposits of fine-grained materials. Thus, throughout most of the study area there appear to be minimal barriers to vertical transport of contaminants through unsaturated soils to underlying groundwater.

GROUNDWATER MOVEMENT

Preceding sections have described groundwater surface elevations and subsurface lithology within the major area of focus of this study. This section describes the apparent movement of groundwater in response to the groundwater surface gradients, aquifer characteristics, and barriers to groundwater movement.

Barriers to Groundwater Movement

Overall, the major barriers to groundwater movement in the study area are the local outcroppings of the Pelona Schist. These outcroppings divide the study area into subareas by isolating sections of the basin.

The Shandin Hills, Wiggins Hill, Perris Hill, and Badger Hill are all outcroppings of the Pelona Schist formation. These hills generally trend in a WNW to ESE direction. These outcroppings appear to be the highest peaks of a range of hills now largely buried under alluvium. Figures 35a and 35b have been added to show these hills and the alluvium between them.

The outcroppings themselves are obvious barriers to groundwater movement. By virtue of their extent, the Shandin Hills effectively divide the major area of focus of this study into two subareas generally lying northeast and southwest of the axis of the Shandin Hills. These two subareas combine to the south and southeast of the Shandin Hills.

In addition to the visible outcroppings, buried saddles in the Pelona Schist formation could influence groundwater flow by restricting the hydraulic capacity between neighboring outcroppings. Such restrictions might be particularly important in the gaps between the Shandin Hills and Perris Hill and between the Shandin Hills and Wiggins Hill.

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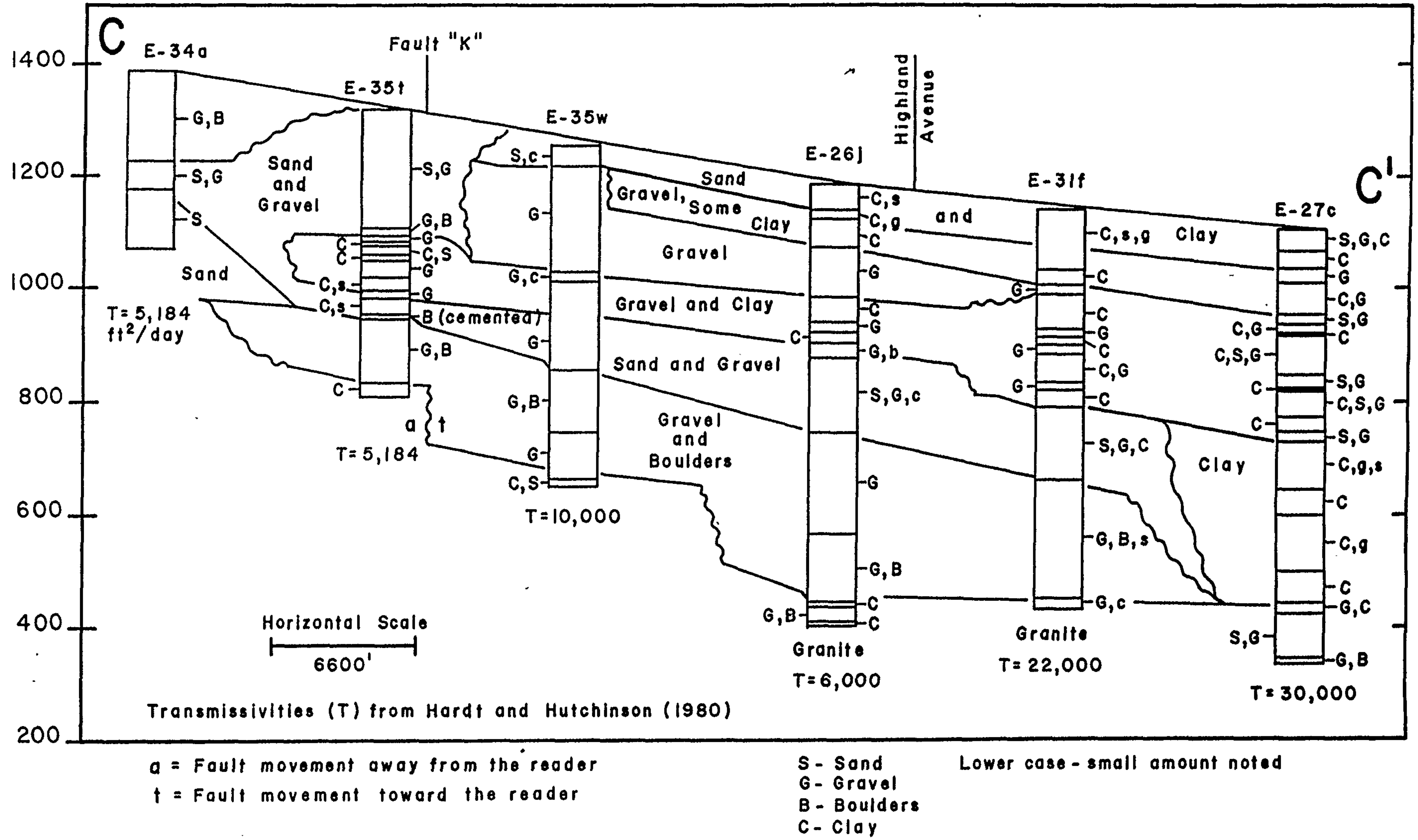

Figure 35. GEOLOGIC SECTION C-C'

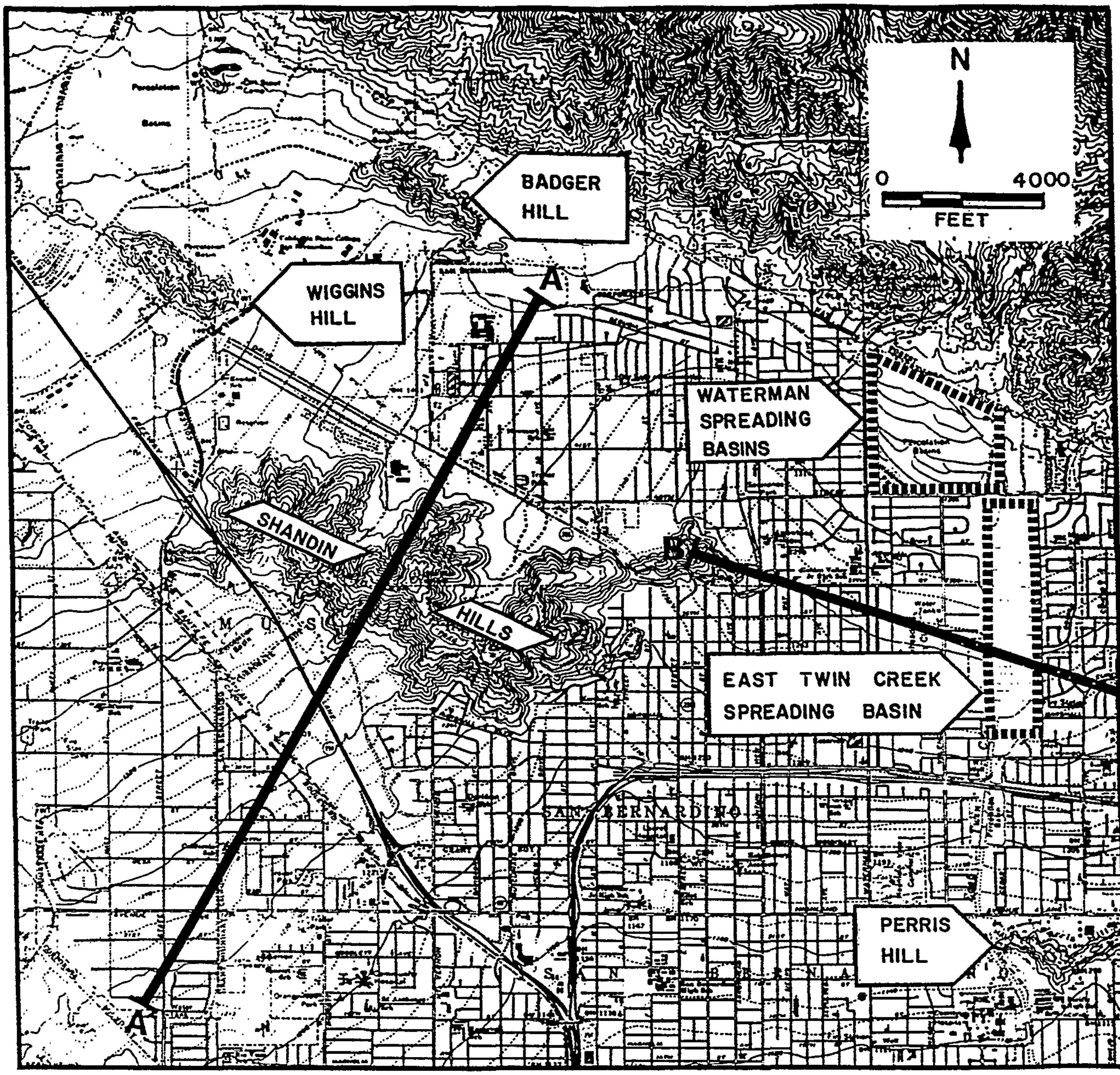

Figure 35a. LOCATIONS OF TWO CROSS-SECTIONS BY
GARY S. RASMUSSEN & ASSOCIATES (April 1985)

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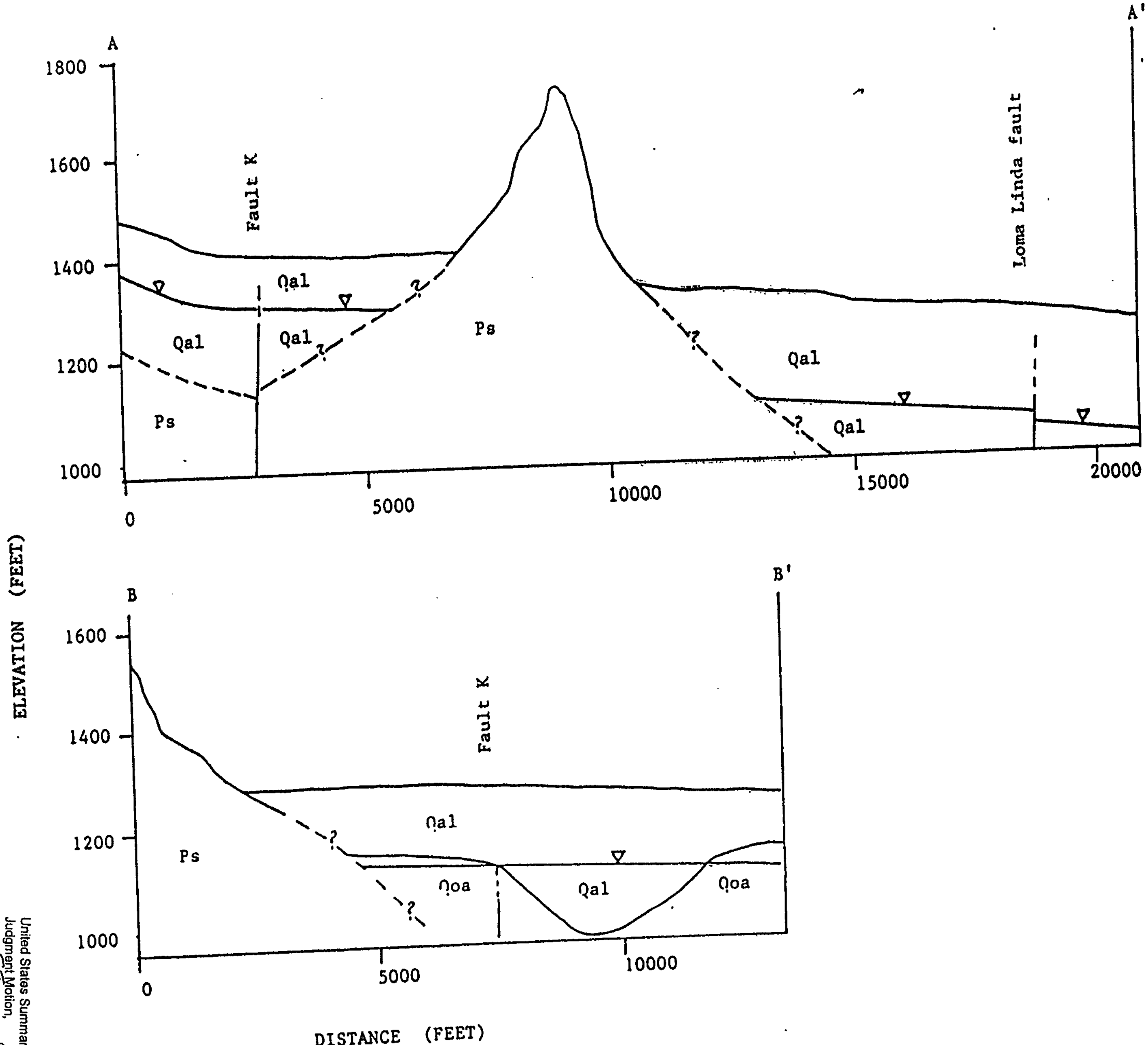

Figure 35b. CROSS-SECTIONS A-A' AND B-B' FROM RASMUSSEN (April 1985)

Data on depth of alluvium presented by Fife et al. (1976) indicate these saddles are buried under hundreds of feet of alluvium. For example, in the gap between the Shandin Hills and Wiggins Hill, the alluvium is reportedly as thick as 400 feet. (By contrast the top of Wiggins Hills is only about 300 feet above the surrounding terrain.) Similarly, Fife et al. report up to 800 feet of alluvium present in the gap between Shandin Hills and Perris Hill. In addition, outside these gaps no significant immediate thickening of alluvial deposits is reported. Thus, it appears unlikely that there are buried ridges which significantly impede groundwater flow in these gaps between the observed Pelona Schist outcroppings. Figure 35c has been added to to show that water-bearing parameters in the Bunker Hill basin generally are thought to range over very wide depth, namely 0 to 5,000 feet.

Faulting is an additional potential barrier to groundwater movement in the study area. Figure 32 depicted major faults identified in the study area. Within the major area of focus the only potential fault barrier to groundwater movement to the south is a Pleistocene age fault identified as "Fault K" on Figure 32.

In view of the reports summarized previously regarding the potential importance of this fault as a groundwater barrier, considerable effort was devoted to the following questions regarding Fault K:

- Are Fault K and the fault on the north side of Wiggins Hill, reported by Dutcher and Garrett (1963) the same fault?
- If Fault K is continuous between the Del Rosa and Wiggins Hill areas, what effect does it have on local groundwater movement?

Concerning the first question, several authors (e.g., Rasmussen, October 1985 and April 1985; and Bechtel Incorporated, March 1970) have mapped an inferred continuous fault through the study area. This mapping, however, appears to have been based primarily on the relative orientations and positions of the faults rather than any direct evidence of fault continuity in this region. The San Bernardino Valley Municipal Water District (1968), however, presented results of gravimetric traverses conducted by Dr. Stephen Dana of the University of Redlands Geology Department, who reported consistent evidence for Fault K (which he termed the Shandin Hills Fault) from northwest of our study area to southeast of the study area. Far to the eastward, he reported, his gravimetric data no longer indicated evidence of faulting.

Warner and Moreland (1972) concluded that Fault K exhibited barrier effects in the area of the Twin Creek spreading grounds. Their conclusion was based on the following factors:

- A 40 to 50 foot difference in water levels they found in wells on either side of Fault K;
- An abnormally large pumping depression associated with one well (1N/4W-25C2), indicating a possible nearby boundary;

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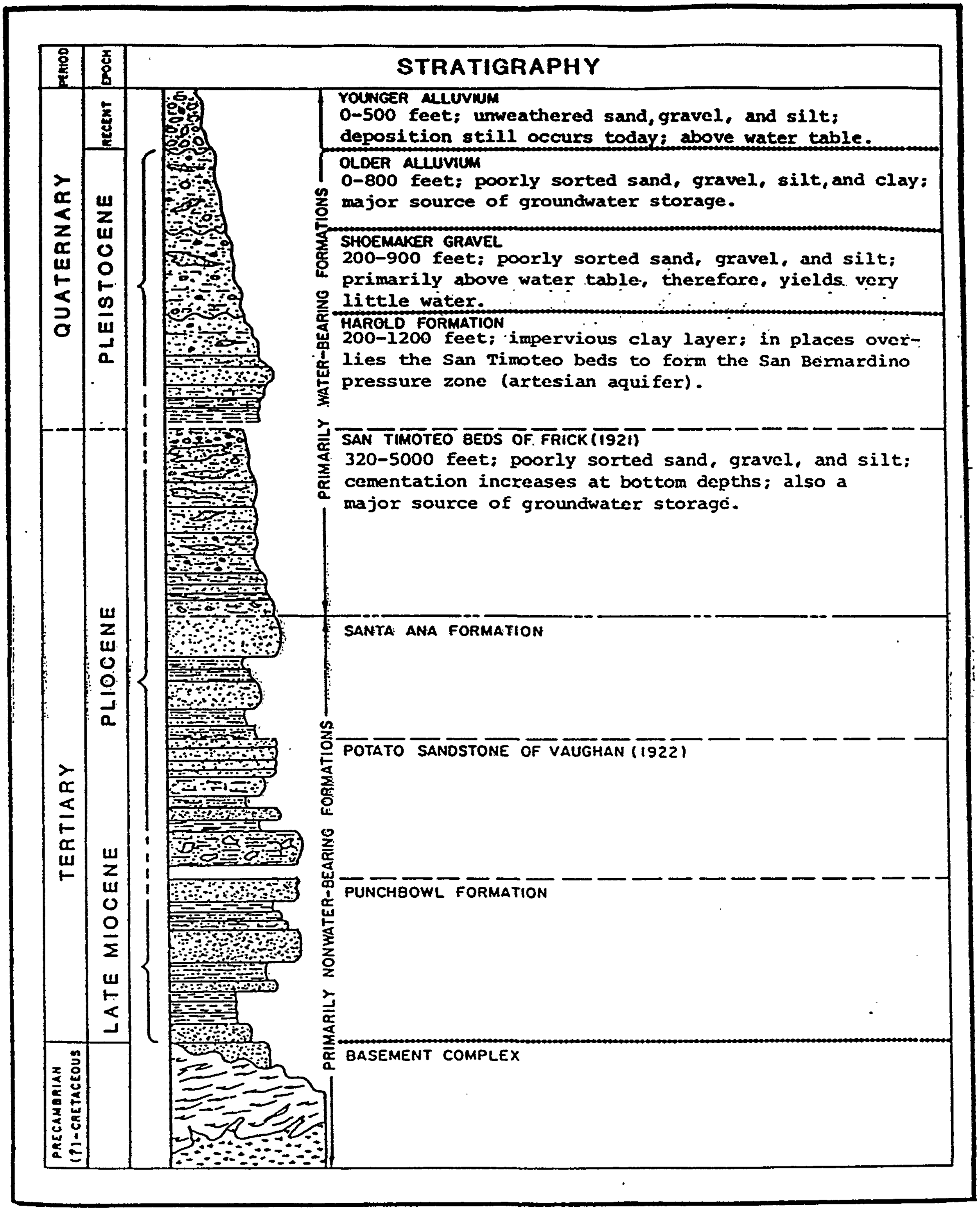

Figure 35c. GENERALIZED CROSS-SECTION OF THE "BUNKER HILL AREA" REPORTED BY STETSON ENGINEERS INC. (1983)

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- Field observations of cemented aquifer conditions, indicating possible smearing or plugging from fault movements; and

- The gravimetric work by Dana (San Bernardino Valley Municipal Water District, 1968).

Based on all the available data, we have postulated that Fault K is continuous with the Wiggins Hill Fault. The evidence that "Fault K," the "Shandin Hills Fault," and the "Wiggins Hill Fault" are all the same structure is convincing. Their features align, and the gravimetric data indicate continuity from several miles west to several miles east of the study area. Accordingly, Figure 32 depicts Fault K as a continuous feature through this area.

In relation to regional groundwater movement, however, Fault K does not appear to be a significant groundwater flow barrier in the study area except near the Twin Creek wash. This conclusion is based primarily on the lack of data indicating anomalies in groundwater surface elevations, but is also supported by structural geologic considerations, described below.

The groundwater surface elevation data given in Figures 29 through 31 reveal no major flow restrictions in the vicinity of Fault K west of Waterman Avenue. Wells 36 and 38 are north of Fault K, whereas wells 20, 28, and 29 are south of Fault K. The groundwater surface gradient between these groups does not show anomalous behavior. Consequently, Fault K does not appear to be a groundwater flow impediment in this area. It should be emphasized that examination of flow patterns on a more detailed level (involving closely-spaced monitoring wells along Fault K) might indicate some localized barrier effects.

There are also structural aspects associated with Fault K that suggest it would not be an important groundwater barrier. These features include the following:

- The nature of the aquifer materials;

- Scissors-type fault movement and lack of dip-slip movement in the Shandin Hills area; and

- Continuing erosion and deposition of alluvium across the fault contact.

As described previously, Section A-A' (Figure 33) closely parallels the inferred location of Fault K. Except in the extreme easterly portions of this section, the aquifer is comprised almost exclusively of coarse granular materials which are not likely to smear or plug in the case of differential movement. In addition, there are few silt or clay lenses to impair permeability in case of vertical displacement or offset.

Note, however, that the lithology becomes more complex in the easterly direction along this section. Thus near the eastern edge of Section A-A', differential movement might result in the offsetting of less permeable formations against more permeable formations, resulting in Fault K possibly becoming a more effective groundwater barrier in that area. This is also supported by its original mapping as an inferred fault by Dutcher and Garrett (1963) based on temperature differences in well waters and groundwater surface elevation anomalies. In addition, Bechtel (1970) and Warner and Moreland (1972) reported finding water level offsets in the vicinity of Fault K in the Twin Creek Wash area.

A second structural issue is an apparent scissoring of Fault K in the vicinity of the Shandin Hills. Dutcher and Garrett (1963) and the San Bernardino Valley Municipal Water District (1968) both reported that the "Shandin Hills" and "Wiggins Hill" faults are downdropped to the north and uplifted to the south. In contrast, Dutcher and Garrett (1963) reported that "Fault K" is uplifted to the north and downdropped to the south. These conclusions suggest that Fault K is a scissors fault, with the hinge located in the northeast Shandin Hills area. (This is not an unusual tectonic pattern for faulting in southern California.) Because the hinging behavior would not cause significant vertical offsets in the hinge area, relatively less impairment of groundwater flow would be expected near the hinge.

Barrier effects across Fault K are also likely to have been reduced by continuing fluvial activity in recent geologic history. By consensus of most geologists, Fault K is considered to be an "inactive" fault with no movement in latest Cenozoic (Pleistocene or later) time (Clopine 1986; Rasmussen, April 1985). Thus the Holocene alluvium would not be faulted and, hence, would not pose any barriers to groundwater flow. Furthermore, it is entirely possible that within Holocene time, pre-Holocene deposits have been repeatedly dissected and subsequently refilled with younger alluvium. This type of activity would tend to further diminish the effectiveness of Fault K as a groundwater barrier, particularly during basin filling when more of the Holocene deposits would be saturated. As described previously, groundwater levels in the area have risen substantially since 1973, so TCE and PCE movements since 1980 -- when these organics were first discovered in local wells -- have likely not been affected by Fault K.

Historical Groundwater Flow Rates

Interstitial water velocity can be calculated from Darcy's Law as follows:

$$V = (K \times S)/P$$

where,
- V = groundwater flow velocity
- K = aquifer hydraulic conductivity = T/d
- T = aquifer transmissivity
- d = thickness of aquifer
- S = groundwater surface gradient
- P = porosity of the aquifer materials.

To use this equation to calculate groundwater flow velocities, the aquifer was divided into elements and the groundwater surface gradient and hydraulic conductivity were determined for each element. The estimated flow velocity for each element was then calculated from these data.

The aquifer elements were extracted from the U.S. Geological Survey finite-element model for the Bunker Hill Basin (Hardt and Hutchinson 1980). Figure 36 shows the area covered by the elements used in this study.

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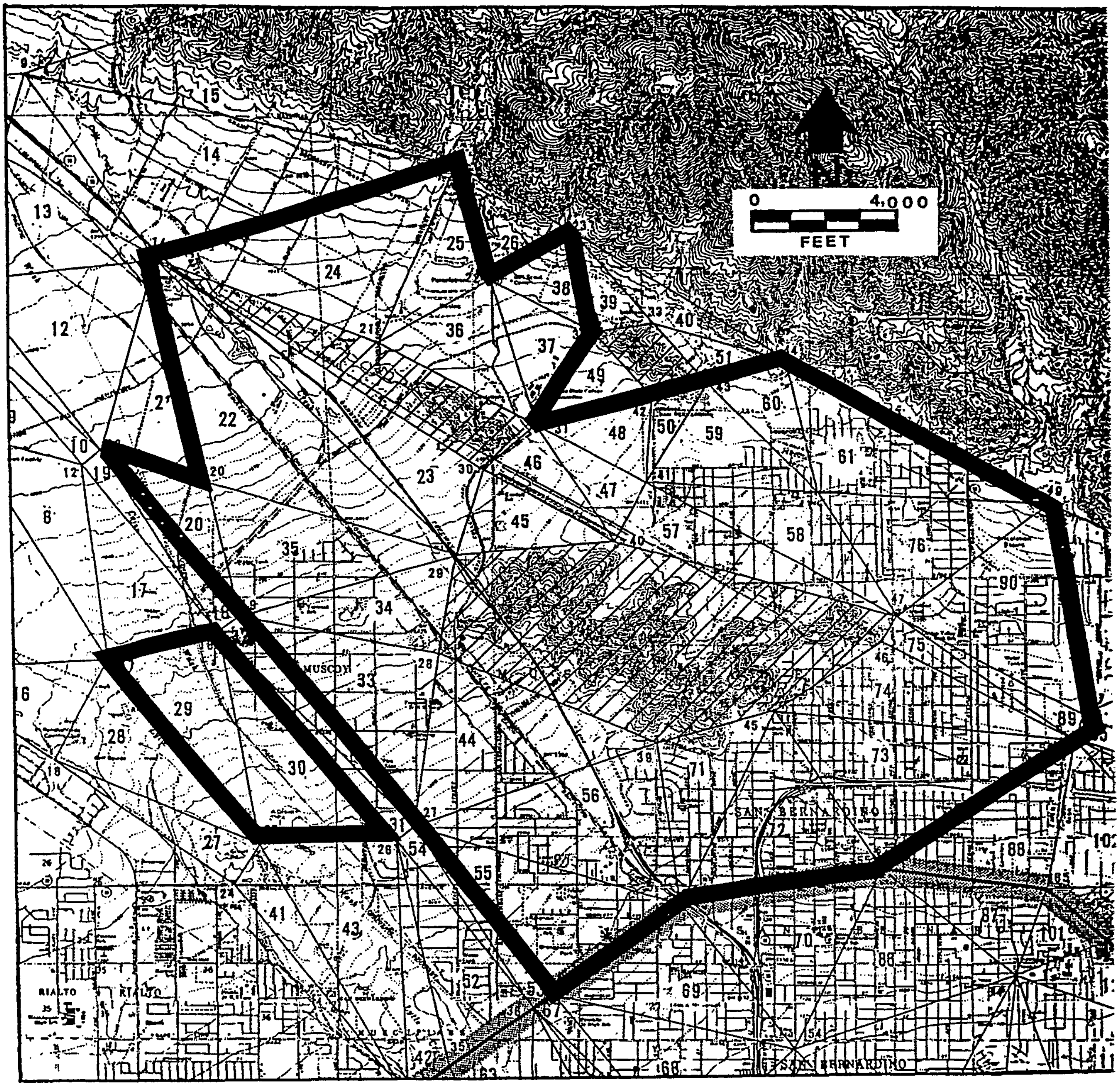

Figure 36. USGS MODEL ELEMENTS FOR WHICH GROUNDWATER FLOW VELOCITIES WERE ESTIMATED

(Source: Hardt and Hutchinson, 1980)

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Transmissivities for each element were taken from the same report. The average depth of alluvium was estimated from the data from Fife et al. (1976), as reported by Rasmussen (October 1985). As the model is built on a two-layered aquifer system, transmissivity values for the upper and lower layers were generally averaged to estimate the transmissivity for each element. Because the transmissivities of the upper and lower layers were generally within 25 percent of each other for most elements, this is a reasonable approximation. In two cases (elements 75 and 89) there were substantial differences between transmissivities for the upper and lower aquifers. In these cases, the transmissivity value for the upper aquifer was used. (It is interesting to note that these two elements are long and narrow, and they were obviously drawn this way by USGS (Hardt and Hutchinson, 1980) to represent Fault K. They were assigned identical transmissivity values by the modelers, and it is doubly interesting to note that they were assigned the 4th-largest values of transmissivity of the 29 elements used here.)

Groundwater flow velocities in the aquifer pore spaces were calculated by multiplying the groundwater surface gradients (scaled from Figures 29 to 31) times the transmissivities from the USGS model, and dividing by the depths of saturated alluvium from Fife et al. and by the porosity of each model element. The values of porosity (ranging from 0.3 to 0.4) were taken from Todd (1980), who lists porosities for general aquifer materials of the Bunker Hill type ranging from 28 percent for coarse gravel to 42 percent for clay.

The selected data and the computed transport rates for groundwater are shown in Table 4 for 1965, 1975, and 1985. Also shown are contaminant (PCE) transport rates, which are simply the velocities divided by 3.0, our chosen retardation factor.

The range of historical groundwater velocities shown in the table is from 0.09 to 5.92 feet per day, or .00625 to 0.41 mile per year. Travel times, then, are the inverse of velocity which range from 160 down to 2.4 years per mile of travel. The range of PCE transport rates was, obviously one-third that of the water: 0.03 to 1.97 feet per day; the unit travel time being 480 down to 7.3 years per mile.

The interstitial water can be seen, therefore, to have moved through the basin at typically very low rates. Groundwater does not move very fast; Todd (1980) reports that while the rates vary widely, "values from 2 meters/year to 2 meters/day are normal." The 0.09 feet/day found here is equivalent to 10.0 meters/year, and the largest velocity found here of 5.92 feet per day is equivalent to 1.8 meters/day. So the computed Bunker Hill basin velocities are within what Todd (1980) has termed the "normal" range.

The hydrogeologic report prepared by Rasmussen (April 1985) for the San Bernardino Municipal Water Department was a precursor to the October 1985 report by Rasmussen to the same client on TCE and PCE flow paths through the same region covered by this study. The April 1985 report (Rasmussen) contained very useful background information on the geology and aquifer characteristics of the area, which we appreciated having. It concluded, as we have, that Fault K is not an important or significant barrier to groundwater movement between the Shandin Hills and Perris Hill; it influenced our interpretation of the Shandin Hills as a major separation of groundwater flow in the

Table 4.

COMPUTED GROUNDWATER AND CONTAMINANT TRANSPORT RATES

					Water Table Surface Gradient						Groundwater (GW) and Contaminant (CON) Transport Rates, ft/day											
					1965		1975		1985		1965				1975				1985			
											Spring		Fall		Spring		Fall		Spring		Fall	
Elmt. No.	Est. Por., p	Avg. T, ft^2/d	Alvm Depth, ft	Hyd. Cond., ft/d	Spring	Fall	Spring	Fall	Spring	Fall	GW	CON	GW	CON	GW	CON	GW	CON	GW	CON	GW	CON
20	0.35	6178	400	15.44	0.017	0.021	0.019	0.020	0.016	0.015	0.75	0.25	0.93	0.31	0.84	0.28	0.88	0.29	0.71	0.24	0.66	0.22
22	0.37	6178	500	12.35	0.016	0.022	0.022	0.024	0.016	0.015	0.53	0.18	0.73	0.24	0.73	0.24	0.80	0.27	0.53	0.18	0.50	0.17
23	0.30	2061	300	6.87	0.022	0.023	0.024	0.025	0.020	0.017	0.50	0.17	0.53	0.18	0.55	0.18	0.57	0.19	0.46	0.15	0.39	0.13
29	0.33	8873	700	12.67	0.017	0.021	0.019	0.020	0.016	0.015	0.65	0.22	0.81	0.27	0.73	0.24	0.77	0.26	0.61	0.20	0.58	0.19
30	0.33	6783	700	9.69	0.017	0.021	0.019	0.020	0.016	0.015	0.50	0.17	0.62	0.21	0.56	0.19	0.59	0.20	0.47	0.16	0.44	0.15
33	0.38	6178	400	15.44	0.017	0.021	0.019	0.020	0.016	0.015	0.69	0.23	0.85	0.28	0.77	0.26	0.81	0.27	0.65	0.22	0.61	0.20
34	0.38	6178	200	30.89	0.017	0.021	0.019	0.020	0.016	0.015	1.38	0.46	1.71	0.57	1.54	0.52	1.62	0.54	1.30	0.44	1.22	0.40
35	0.36	6178	200	30.89	0.017	0.021	0.019	0.020	0.016	0.015	1.46	0.49	1.80	0.60	1.63	0.54	1.72	0.57	1.37	0.46	1.29	0.43
44	0.37	5707	400	14.26	0.017	0.021	0.019	0.020	0.016	0.025	0.66	0.22	0.81	0.27	0.73	0.24	0.77	0.26	0.62	0.21	0.96	0.32
45	0.38	2061	100	20.61	0.014	0.022	0.019	0.025	0.015	0.012	0.76	0.25	1.19	0.40	1.03	0.34	1.36	0.45	0.81	0.27	0.65	0.22
46	0.38	4225	200	21.12	0.014	0.022	0.019	0.025	0.015	0.012	0.78	0.26	1.22	0.41	1.06	0.35	1.39	0.46	0.83	0.28	0.67	0.22
47	0.38	4968	200	24.84	0.014	0.009	0.019	0.025	0.018	0.012	0.92	0.31	0.59	0.20	1.24	0.41	1.63	0.54	1.18	0.39	0.78	0.26
48	0.38	2320	200	11.60	0.014	0.022	0.048	0.017	0.018	0.028	0.42	0.14	0.67	0.22	1.47	0.49	0.52	0.17	0.55	0.18	0.85	0.28
50	0.38	2320	200	11.60	0.034	0.040	0.048	0.029	0.018	0.028	1.04	0.35	1.22	0.41	1.47	0.49	0.89	0.30	0.55	0.18	0.85	0.28
55	0.40	8238	800	10.29	0.017	0.021	0.019	0.020	0.016	0.013	0.44	0.15	0.54	0.18	0.49	0.16	0.51	0.17	0.41	0.14	0.33	0.11
56	0.39	8238	700	11.26	0.017	0.021	0.019	0.020	0.016	0.029	0.51	0.17	0.63	0.21	0.57	0.19	0.60	0.20	0.48	0.16	0.88	0.29
57	0.38	4968	100	49.68	0.013	0.011	0.015	0.017	0.018	0.015	1.70	0.57	1.44	0.48	1.96	0.65	2.22	0.74	2.35	0.78	1.96	0.65
58	0.38	2320	200	11.60	0.013	0.053	0.048	0.056	0.018	0.015	0.40	0.13	1.62	0.54	1.47	0.49	1.71	0.57	0.55	0.18	0.46	0.15
59	0.38	2320	200	11.60	0.013	0.048	0.048	0.029	0.018	0.028	0.40	0.13	1.47	0.49	1.47	0.49	0.89	0.30	0.55	0.18	0.85	0.28
60	0.38	467	200	2.34	0.048	0.048	0.060	0.040	0.018	0.028	0.29	0.10	0.29	0.10	0.37	0.12	0.25	0.08	0.11	0.04	0.17	0.06
61	0.30	700	200	3.50	0.064	0.053	0.074	0.056	0.018	0.028	0.75	0.25	0.62	0.21	0.86	0.29	0.65	0.22	0.21	0.07	0.33	0.11
71	0.39	6187	400	15.46	0.005	0.006	0.004	0.006	0.009	0.020	0.20	0.07	0.24	0.08	0.16	0.05	0.24	0.08	0.36	0.12	0.79	0.26
72	0.38	6501	750	8.67	0.017	0.006	0.004	0.006	0.009	0.020	0.39	0.13	1.37	0.46	0.09	0.03	1.37	0.46	0.31	0.07	0.46	0.15
73	0.36	10429	500	20.85	0.022	0.017	0.006	0.017	0.016	0.014	1.27	0.42	0.98	0.33	0.35	0.12	0.98	0.33	0.93	0.31	0.81	0.27
74	0.35	13034	300	43.44	0.022	0.017	0.007	0.017	0.016	0.033	2.73	0.91	2.11	0.70	0.87	0.29	2.11	0.70	1.99	0.66	4.10	1.37
75	0.40	8096	300	26.98	0.012	0.017	0.020	0.040	0.019	0.014	0.81	0.27	1.15	0.38	1.35	0.45	2.70	0.90	1.28	0.43	0.94	0.31
76	0.35	2204	200	11.02	0.074	0.074	0.080	0.040	0.053	0.120	2.33	0.78	2.33	0.78	2.52	0.84	1.26	0.42	1.67	0.56	3.78	1.26
89	0.40	8096	300	26.98	0.012	0.017	0.020	0.040	0.019	0.014	0.81	0.27	1.15	0.38	1.35	0.45	2.70	0.90	1.28	0.43	0.94	0.31
90	0.35	5184	300	17.28	0.083	0.074	0.080	0.071	0.019	0.120	4.10	1.37	3.65	1.22	3.95	1.32	3.51	1.17	0.94	0.31	5.92	1.97

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study area into two distinct southeasterly paths; and it introduced us to literature we also found and reviewed. The report also lamented that "The rate at which the contaminated water is moving is not known;" and it also said, despite the work by Water Resources Engineers (1969) and the USGS modeling work reported by Hardt and Hutchinson (1980) and by Mallory (1979), that, "None of the studies conducted on the basin to date indicates the time it takes ground-water to move from one part of the basin to another." The report also placed great emphasis on the potential of recharge at the upper end of the basin, specifically the Devil Canyon and Waterman Canyon - Twin Creek spreading basins, to influence the rate at which water is moved through the basin.

In his textbook on groundwater hydrology, Todd (1980) gives reported values of recharge rates in managed recharge basins throughout the United States, most of which were in California. The range of recharge rates (presumably the rate of fall of the ponded water, not the interstitial flow velocity) was 0.1 to 2.9 meters per day (0.33 to 9.5 ft/day). One of Todd's (1980) reported locations was the Santa Ana River basin, where the recharge rates were reported to vary between 0.5 and 2.9 meters per day. Note that this basin displayed the highest rate in Todd's sample of 15 locations. Converting these rates to interstitial velocities in other units yields 1,620 to 9,400 ft/yr or 4.1 to 23.5 years per 38,000 feet, the distance from the Waterman Canyon spreading basin to the lower end of the Bunker Hill basin. Quite naturally, not water travels through the entire basin at these rates; these are the rates at which water percolates or "falls" 100 feet or less down to the water table.

The median values of the factors that affect groundwater velocity in the model elements used and reported in Table 4 were

$$
\begin{aligned}
T &= 6{,}000 \text{ ft}^2\text{/day (transmissivity)} \\
b &= 300 \text{ ft (aquifer thickness)} \\
dH/dL &= 0.018 \text{ ft/ft (water table gradient)} \\
P &= 0.37 \text{ (porosity)}
\end{aligned}
$$

From Darcy's law, it is apparent that travel time can be computed from

$$t = \frac{PL}{(T/b)(dH/dL)}$$

If the median values of the Table 4 parameters characterized the entire San Bernardino Valley portion of the Bunker Hill basin, therefore, the travel time in the saturated zone from the point of recharge to the lower end would be

$$t = \frac{(0.37)\ (38{,}000)}{(6{,}000/300)(0.018)} = 39{,}056 \text{ days} = 107 \text{ years}$$

The travel time for pollutants would be increased by R times, where R is the retardation factor.

Lastly, we note from Figures 29 through 31, from the groundwater contours in the study area (upstream of the artesian, pressure zone), and from 1975 contours for the entire Bunker Hill basin given by Hardt and Hutchinson (1980), that the groundwater-level surface has ranged from 1,300 feet elevation near the recharge zone down to 950 feet elevation at the lower end of the basin 38,000 feet away. These data indicate an approximate groundwater flow velocity in the pore spaces of

$$v = (T/b)\ (dH/dL)/(P) = (20\ \text{ft/day})\ (350/38{,}000)/0.37$$

$$= .498\ \text{ft/day} = 182\ \text{ft/year}$$

The travel time, therefore, would be

$$t = \frac{38{,}000\ \text{ft}}{182\ \text{ft/yr}} = 208\ \text{years}$$

These computations were all considered in determining whether or not it is plausible for a single source or a few large sources in the northwestern, upgradient part of the study area to have been the source for all the TCE and PCE pollution now to be found in wells throughout the 15 square mile study area. We believe the average travel time for the water to flow roughly 5 miles from the apparently largest but most remote sources (Camp Ono and the San Bernardino Airport) through the study area would require

$$t = \frac{0.37\ (5\ \text{mi} \times 5{,}280\ \text{ft/mi})}{(6{,}000\ \text{ft}^2/\text{day})/(300\ \text{ft})(0.018\ \text{ft/ft})(365\ \text{days/yr})} = 74\ \text{years}$$

That is a conclusion based on measured water level gradients and average aquifer characteristics in the USGS model (Hardt and Hutchinson, 1980). Others have speculated on the basis of only water level changes in wells that the speed must be 38,000 ft/yr and hence a 5-mile travel time must be a little over 8 months. We are convinced that the 8-month estimate results from observing pressure translation and not water movement, and the 8 months be more nearly what Rasmussen (April 1985) has called an "instantaneous" period for even pressure to be translated 5 miles in the real world of saturated porous media.

We point out that even the calculations given herein are averages; water in the pressure zone moves more slowly than in the unconfined aquifer area of this study (Rasmussen, April 1985); water near pumping wells travels faster than the average regional flow-field velocity; and very localized solution channels or other features of locally higher-than-average permeability will result in much higher flows. In that light, we have computed radiuses of influence for the 30 municipal wells listed earlier in Table 3 from pumpage data for the 1979 to 1983 period. The results, including the areas of influence are given in Table 5. The sum of all the areas of influence of the wells, pumping at their maximum recorded annual rate, is 4.3 square miles or 29 percent of the area if the Newmark wells are combined. The areas of influence of all wells other than the Newmark wells sum to 1.95 square miles or 13 percent of the 15 square mile area. The maximum flows for each well were chosen from 5 years of pumpage data, so these maximum flows did not all occur at the same time (i.e., the area influenced by higher-than-average velocities was less than Table 5 suggests). It is also to be noted that the radius of influence, computed from (Todd, 1980) as:

$$r = \frac{Q}{2(T/b)(H)(dH/dL)}$$

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Table 5.

MAXIMUM ZONES OF INFLUENCE OF MUNICIPAL WELLS
1979-1983

Well Number	Local Designation	Highest Annual Flow in Period,[1] gpm	Estimated Radius of Influence, feet	Estimated Area of Influence, sq. mi.
1	Antil #6	2,918	2,600	0.760
2	Arrowhead Country Club	279	429	0.007
3	Baseline & California	376	335	0.013
4	Colima	192	171	0.003
5	Darby	90	80	0.001
6	Ellena Brothers	482	430	0.021
7	Gardena	150	134	0.002
8	Gilbert	0	0	0
9	Leroy	813	725	0.059
10	Lynwood	798	711	0.057
11	Lytle Creek #3	1,308	1,166	0.150
12	Mallory	66	59	0.000
13	Mt. Vernon	289	258	0.007
14	Newmark #1	807*		
15	Newmark #2	1,591*		
16	Newmark #3	1,045*		
17	Newmark #4	1,708*	Sum *'s = 4,590	2.37
18	Perris Hill #5	472	421	0.020
19	State Street	116	103	0.012
20	Waterman Avenue	1,995	1,778	0.356
21	7th Street	1,863	1,660	0.311
22	16th & Sierra Way	0	0	0
23	17th & Sierra Way	0	0	0
24	19th St. No. 1	550	490	0.027
25	19th St. No. 2	366	326	0.012
26	23rd & No. "E" St.	0	0	0
27	25th & No. "E" St.	269	240	0.006
28	27th & Acacia	0	0	0
29	30th & Mt. View	769	685	0.053
30	31st & Mt. View	929	828	0.077

[1] Source: Annual Report of the Western - San Bernardino Watermaster for 1984, August 1, 1985.

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implies that water was moved toward the well from all directions (radially) at higher-than-average velocities, which modulates this effect on regional flow-field velocities substantially if not totally.

CORRELATIONS OF TCE AND PCE CONCENTRATIONS WITH HYDROGEOLOGIC FACTORS

In an appendix to the Task I report, plots were given of TCE and PCE concentrations in each of the contaminated and closed municipal wells for the years 1980 to 1985. Those data, provided by the Department of Health Services and the City of San Bernardino, have served in part as the basis for hypotheses by others of perhaps two or as many as three significant sources in the northwest region of the study area from which contaminants have been spread by regional groundwater flow in plumes extending across the study area (Rasmussen, October 1985).

The average flow velocities and retardance factors just discussed, however, bring this single-source or few-source, broad-and-extensive plume theory into question. In Table 6 the water and PCE travel times are computed from the Table 4 data and from specific travel paths through USGS model elements that would have been followed from the upgradient sources to downgradient wells. The table shows that the travel time for the water to move from Newmark to Waterman Avenue through the specific aquifer materials in-between would have taken more than 20 years, and the PCE (with retardance affecting it) would have taken more than 60 years. Also the travel times along a more southerly path from Camp Ono to the Darby Street well would have been about 55 years for the water and 170 years for the organic contaminant, given a retardation factor of 3.0.

Camp Ono and the San Bernardino Airport are the two sources most often implicated in the single-source, dispersed-plume theory. These potential sources, however, did not exist until the 1940s (Camp Ono) and the 1950s (airport). The airport is immediately adjacent to the Newmark wellfield, and airport shop activity may well have been responsible for the Newmark contamination. But the other closed wells in San Bernardino appear to be too far from Ono or the airport for contaminants to have reached the other closed wells during the roughly 40 years since those sources opened. Without dismissing the extended-plume, single-source theory altogether it behooves us nonetheless to study other theories to see if an equally plausible or more plausible explanation can be advanced for how the concentration levels and patterns over time could have attained the characteristics that have been observed over the last half-decade at the three widely separated well locations.

Newmark Wellfield

Figure 37 shows the 1980-85 pattern of PCE concentrations at the four wells in the City of San Bernardino's Newmark wellfield. The TCE pattern is identical, although the concentrations measured in these wells have been much lower than PCE concentrations. (The TCE plots were included in the Task 1 report.)

There are many observations about this wellfield that have been made by the City and by URS:

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Table 6.

TRAVEL DISTANCES AND TIMES FROM
REMOTE SOURCES TO TWO WELLS

Model Element Number	Travel Distance[1], miles	Groundwater Velocity[2], feet/day	Water Travel Time[3], yr.	PCE Travel Time[4], yr.
Newmark Wellfield to Waterman Avenue Well -- Fall 1985 Data				
57	1.5	1.96	11.1	33.3
75	0.3	0.94	4.6	13.8
74	0.6	4.10	2.1	6.3
73	0.2	0.81	3.6	10.8
TOTAL:	2.6		21.4	64.2
Camp Ono to Darby Street Well -- Fall 1985 Data				
23	0.4	0.39	14.8	44.4
22	0.4	0.50	11.6	34.8
35	0.35	1.29	3.9	11.7
34	0.6	1.22	7.1	21.3
33	0.3	0.61	7.1	21.3
44	0.8	0.96	12.0	36.0
TOTAL:	2.85		56.5	169.5

1 Scaled from Figure 36.

2 From Table 4

3 Equals (mi x 5,280 ft/mi)/(365 days/yr x ft/day)

4 Equals water travel time x 3.0 (Retardation Factor)

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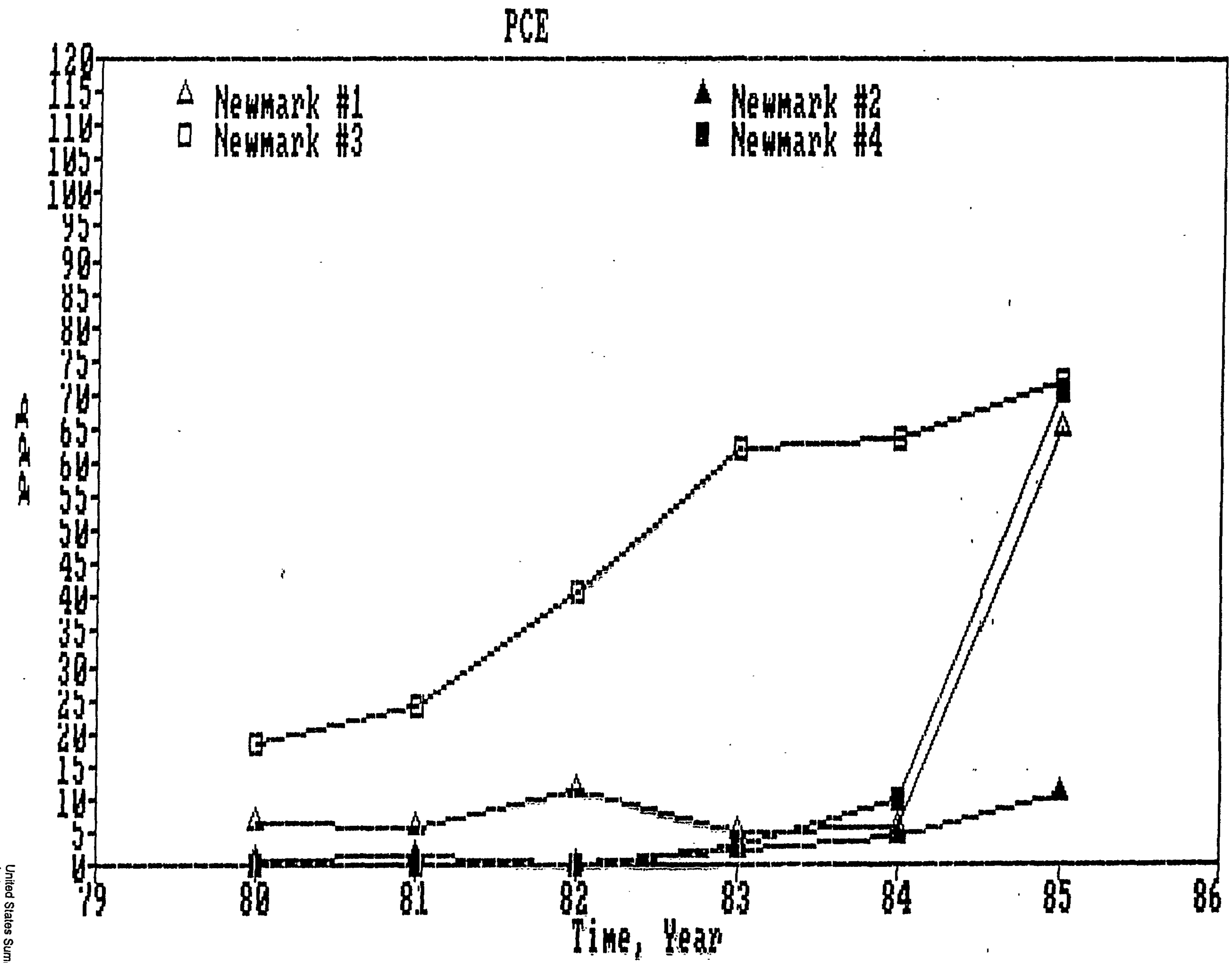

Figure 37. CONCENTRATION PATTERN AT THE NEWMARK WELLFIELD

1. Packer tests made by the City in 1984 showed 50 ppb PCE levels in the lower portion of the aquifer perforated by well #3 at the southern edge of the field, but none was detected at higher levels in the same well. One-fifth to one-tenth as much was found in the other three (shallower and more northerly) wells.

2. Both TCE and PCE concentrations were low in wells 1, 2, and 4 until 1984, when well #3 was turned off. Since then, there have been 10-fold increases in concentrations in wells 1 and 4, which are upgradient of well 2.

3. Regional groundwater flow in the immediate area appears to be to the south-southeast (see Figure 31).

4. Thirty days of pumping at well #3 at a rate of 2,000 gpm would have created a drawdown of approximately 20 feet at the suspected "CAT Pit" source some 300 feet to the west-northwest. That is, well #3 operating at its rated capacity would have generated a cone of depression extending to the suspected nearby source and would have created its own gradient from that source toward the well. Concurrent pumping at other wells in the field would have exerted still further influence on water and contaminant movement from the source toward the wells.

These observations point to the following conclusions about the correlation between the observed concentration patterns at Newmark and the local hydrogeology:

1. PCE and TCE likely entered the wellfield from the south and southwest, as a result of: a) heavy pumping at well #3, b) south-southeasterly groundwater flow patterns, and c) periodic recharge from the west and south. This conclusion is reinforced by the fact that the concentrations increased markedly in the more northerly wells following the close of the most southerly well.

2. Well #2 has been the least affected thus far, probably because it is the furthest from the suspected source and because it is the shallowest well in the Newmark group.

3. Contamination moving 300 feet to the east-southeast into well #3, with a retardance factor of 3, could have reached well #3 in 3 years, given a groundwater velocity of 300 ft/year. Cone-of-depression effects could easily have increased the rate by a factor of 2 and halved the travel time. The "CAT Pit" has been alleged to have been in operation from 1958 to 1963, fully 20 years before the PCE and TCE were first detected in these wells (1980). (Well #3 was drilled in May 1954.)

All the measurements of concentrations in the Newmark wells and the hydrogeologic features of the local area strongly implicate the former airport's shop area several hundred feet west of the wells -- the "CAT Pit" source being the most likely.

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Mountain View - Waterman Area Wells

Figure 38 shows the annual average PCE concentrations measured at the four most easterly contaminated wells (Figure 2) in the north-central region of San Bernardino for the 1980-85 period. These four wells, east of the Shandin Hills, are as much as a half-mile apart. Still, the concentration levels are all low, and patterns of change have been essentially nonexistent since 1980. As identified in Chapter 3, there are numerous existing and historical sources of TCE and PCE near these wells. The aquifer materials in this region are finer than in the Newmark wellfield, and groundwater flow velocities should be lower; and retardance factors should be higher -- on the order of 4 to 6. Hence solvent movement rates should be approximately 50 to 100 ft/year. As shown in Figures 29 to 31, predominant flow paths over the last 20 years have been to the south and southeast. While the 15 potential sources identified were a half-mile to 2 miles upgradient of these wells, the flow velocities and retardance factors indicate that solvents would require at least 60 years to move a single mile in this area.

The long travel times, the persistent and low concentrations of solvents, and the lack of any apparent relationships among the concentration patterns at these four wells strongly imply that the source or sources of contamination for these wells were very near the wells and cannot be expected to have been remote from the area by several miles, as the single-source, broadly-dispersed-plume theory would suggest. The fairly constant pattern of concentrations at these wells also suggests that the plume characteristics of rising, peaking, and falling concentrations to be expected from a single-event, single-spill contamination did not occur. To the contrary, the observed pattern suggests a fairly low-level but continuous source or sources of these solvents.

Muscoy-Delmann Heights Wells

Figure 39 shows the 1980-85 concentrations of PCE found in wells in a third subarea of the study region, the region south and west of the Shandin Hills near Muscoy and the Delmann Heights development (see Figure 2).

These patterns suggest that a plume or plumes of PCE may have moved through this area in 1981, although the contamination has not apparently reached the southernmost of the four wells -- the State Street well.

The Colima and Gardena wells are located fairly close to one another and show virtually identical plume-like, single-spill patterns of contamination, although the more southerly Gardena well has the higher concentrations. Figure 31 showed, however, that the 1985 groundwater gradient was actually to the east-northeast in this area in recent years, in contrast to the earlier east-southeast pattern shown in Figures 29 and 30. Hence, the source of contamination may have been the same for these two wells, and if so the contamination source must be close enough to have contaminated both wells since 1975 (implies less than 4,500 feet away).

The Darby well is to the north-northeast (upgradient) of the other two affected wells by approximately one mile, and its PCE concentration pattern is bimodal, suggesting a different source and a periodic but continuing one.

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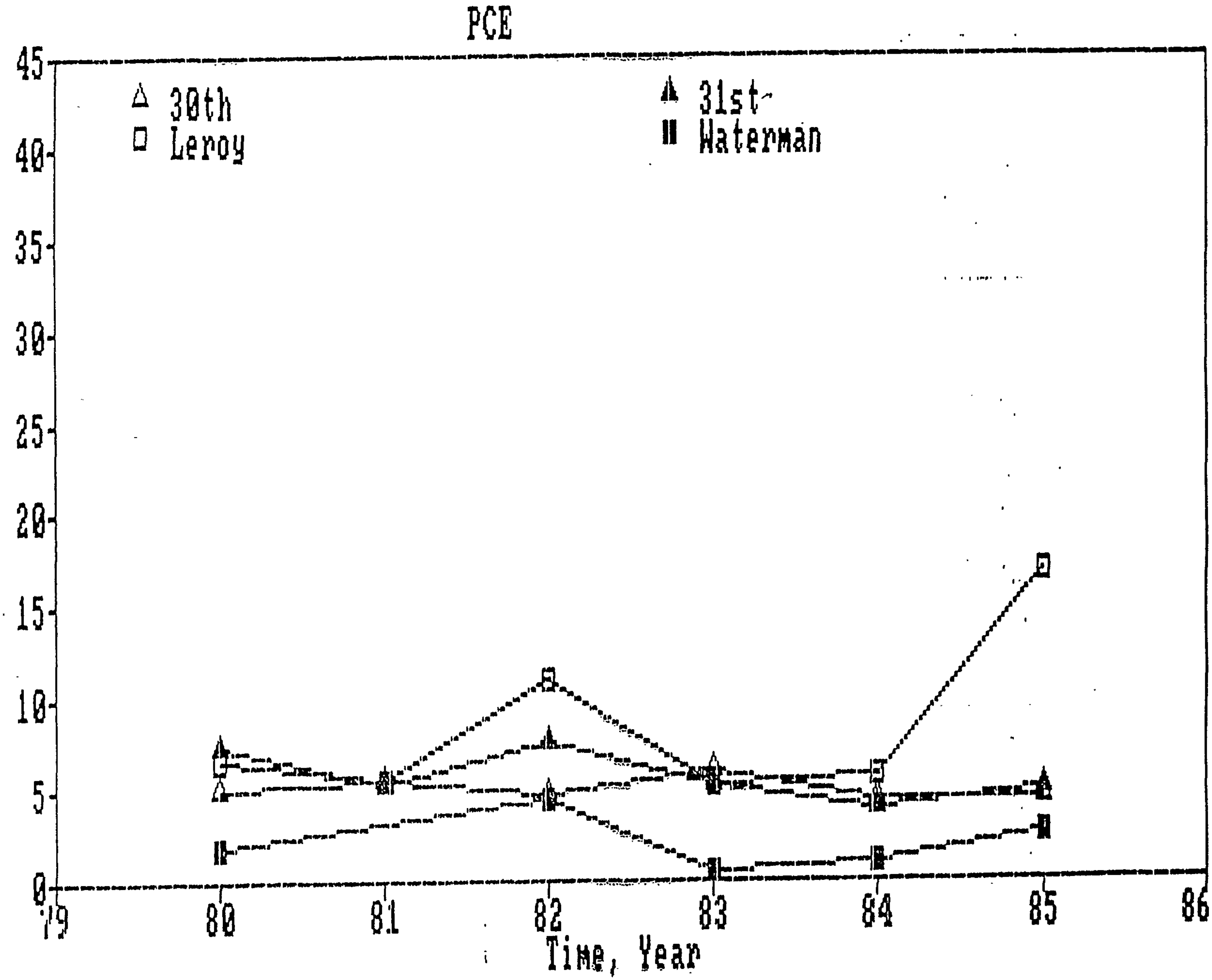

Figure 38. CONCENTRATION PATTERN AT WELLS EAST OF THE SHANDIN HILLS

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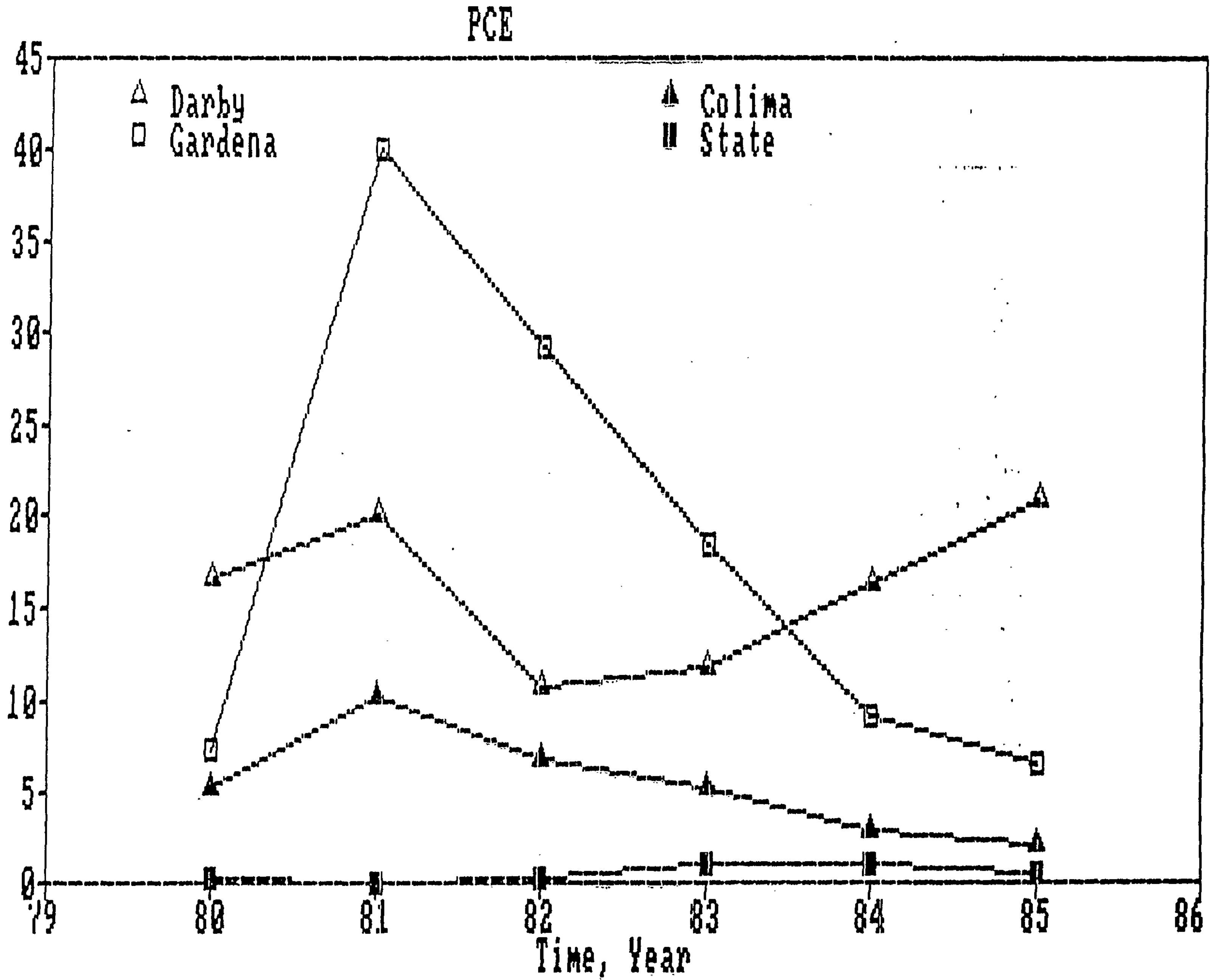

Figure 39. CONCENTRATION PATTERN AT WELLS SOUTH AND WEST OF THE SHANDIN HILLS

There were many potential local sources for contamination of these wells identified in the Task I report. Groundwater flow velocities are roughly 100 ft/year in this region, and retardance factors suggest that solvent movement is around 30 ft/year. Hence, the source or sources of contamination found in these four wells are likely within a very short distance of these wells. Note particularly that the Gardena and Colima wells' PCE levels peaked and receded within a 2-year period (an indicated 60 feet of travel distance for the slug of pollutant).

Lastly we note that the driller's logs for all the wells described here were given in an appendix to the Task II report. Particularly for the Gardena well -- the one with highest PCE concentrations in this group -- well perforations are the shallowest of the four wells. This unique and shallow relationship to ground surface in combination with the highest PCE levels implies a source of ground spill or dumping very near the Gardena well.

ADDITIONAL HYDROGEOLOGIC INFORMATION ANALYZED

URS has reviewed the records of packer tests performed by the City of San Bernardino in 1984 at the Newmark wells which were made to determine if the contamination was isolated at specific depths in the underground aquifer materials. These tests were largely inconclusive, although the greater concentrations at the deepest, most southerly well (well #3) were confirmed, as indicated in the preceding section. Additionally, locations of abandoned wells indicated in Dutcher and Garrett's 1963 mapping were noted, although we were not able subsequently to sample them. If further investigations are contemplated by the Regional Board or others, these abandoned wells may provide accessible sampling points for groundwater at other than merely the municipal wells studied herein.

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Chapter 5.

FIELD INVESTIGATIONS

Field investigations were performed in two phases. The first phase involved area-wide reconnaissance using soil pore gas investigation to identify areas of significantly greater presence of solvents in soil pore gas. Increased levels of solvent in soil pore gas were presumed to reflect either significant concentrations of solvent in area groundwater, or in the case of extremely high concentrations, proximity to sites when solvents had been improperly disposed of..

While TCE was found in gas at only 9 sites, its concentrations among those sites varied over 6 orders of magnitude (values ranged from 0.0002 to 100 micrograms per liter of gas). PCE values at the 102 sites ranged from 0.0005 to 40 micrograms per liter of gas (roughly 5 orders of magnitude). There were, however, only 7 sites at which PCE was detected at levels of 0.1 micrograms per liter or above (0.10 to 40 micrograms per liter of gas). These sites, like the TCE sites, were highly localized and spread throughout the northwestern San Bernardino area. Coincident at 2 of these PCE sites, TCE was also found in high concentrations.

In addition, there was an apparent band of consistently moderate to high PCE levels reported in soil pore gas roughly along an east-west transect near the southern boundary of the study area (Highland Avenue). This feature suggests a potential "line" source of PCE now exists in this area -- all along Highland Avenue, and downgradient wells are now threatened by a contaminated body of water or a number of individual sources much closer to them than Camp Ono or the San Bernardino Airport.

In the second phase, borings were made to collect soil samples for solvent analysis. Boring sites were selected based on the soil pore gas testing results augmented by information on potential sources of contamination identified in Task 1.

Only one of the 84 soil samples analyzed for TCE and PCE showed a barely detectable level (i.e., 0.1 mg/kg) of TCE. This sample was taken from a 34 foot depth at the site having the highest soil pore gas values for TCE and PCE (i.e., 100 micrograms per liter and 4.0 micrograms per liter, respectively) and it was adjacent to the CAT Pit. These samples also had a noticeable chemical odor at the time of collection. No TCE or PCE was detected in any other soil sample. Again, the detection limit was 0.1 mg/kg, which is equivalent to 100 ug/kg; so TCE and PCE may have been present in fairly significant quantities even though they could not be detected.

Auger refusal in other borings at the CAT Pit site at shallow depths precluded sampling for TCE or PCE in those borings. This refusal occurred at depths near the base of the clear fill placed in the CAT Pit after it was abandoned.

SOIL PORE GAS INVESTIGATIONS

The first phase of the field investigation involved sampling and analyzing soil pore gas for halogenated solvents. This is a technique that has proven successful in other settings for identifying sources of potential halocarbon contamination and for tracking the movement of contaminated groundwater.

Selection of Sample Sites

Soil pore gas analysis does not directly measure solvent concentrations in either groundwater or soil. Accordingly, results from this technique should be considered to be semi-quantitative, with greatest applicability to areawide reconnaissance to identify specific areas warranting more detailed attention.

Recognizing these constraints on the soil pore gas analysis procedure, URS and ERM-West jointly selected sites for soil pore gas analysis. These sites were selected in a pattern providing numerous east-west and north-south transects across the study area. The sampling site network was submitted to the California Regional Water Quality Control Board, Santa Ana Region for review and approval prior to beginning the pore gas investigation. (See Figure 40, later herein.)

The spacing between adjacent sample points was about one-quarter to one-third of a mile. A sampling grid of this nature can generally respond to features that are of a scale approximately three times as great as the grid spacing, hence the overall distribution of sampling sites was deemed capable of responding to contamination features of about one mile or greater in dimension. Because the primary objectives at this stage of the study were to identify major groundwater contamination plumes (with concentrations in underlying groundwater roughly between 5 and 150 ug/l) and to assess the theoretical findings that observed contamination patterns could not be attributed to one or a small number of large contamination sources, this overall degree of sensitivity was deemed adequate.

Near the Newmark wellfield and the adjacent CAT Pit site, soil pore gas sample sites were more closely spaced. Closer spacing in this area was dictated by the potential significance of the CAT Pit as a contamination source and the close proximity of the CAT Pit to the Newmark wellfield.

Methods

Soil pore gas sampling for TCE and PCE was performed by Tracer Research Corporation (TRC), a URS subcontractor, on February 24th through February 28th, 1986. Strict quality control procedures were followed. The testing involved a single van and a two-person crew. The van contained hydraulic equipment for implanting 3/4-inch steel pipe in the ground, a vacuum pump to extract pore gas for sampling, and computer-assisted gas chromatography equipment for analyses of the gas samples.

To collect samples, the TRC van was positioned in the immediate vicinity of the selected sample points for which clearances had been obtained from landowners and from gas and electric utility companies. To minimize clearance and right-of-access concerns, most sites were located in street rights-of-way. The soil gas sampler was hydraulically or manually forced into the ground until it was slightly more than 5.5 feet deep. The sampler was then withdrawn several inches, separating it from its metal tip to leave a space through which soil gas at 5.5 feet could be extracted. Several pipe volumes of gas

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were then evacuated from the pipe under negative pressure for 30 seconds. A 10-cc syringe was purged twice with gas from the sampling tube, and a third 10-cc aliquot was retained for analysis.

The sample was then split into two equal aliquots, each injected sequentially into the gas chromatograph. Results reported were the average of the two split samples.

The first pore gas sampling took place at the Newmark wellfield. Pore gas sampled at this site was taken at depths of three feet, five and one-half feet and nine feet to evaluate the influence of probe depth on sample results. Moderate readings for PCE were found at that site, and analyses at the separate depths indicated that sampling at 5.5 feet would provide adequately useful results.

Results

Results of soil pore gas analyses for PCE and TCE, grouped by concentration ranges, are presented in Figures 40 and 41, respectively. Figures 42 and 43 depict soil pore gas results from the more detailed sampling network in the vicinity of the Newmark wells. The results by site are tabulated in Table 7.

The results indicate that PCE was found extensively throughout the area. PCE values at the 102 sites ranged from 0.0005 to 40 micrograms per liter of gas (roughly 5 orders of magnitude). There were, however, only 7 sites at which PCE was detected at levels of 0.1 micrograms per liter or above (0.10 to 40 micrograms per liter of gas). In addition, spot checks of ambient air during the work indicated low and continuously increasing concentrations of PCE during the course of the week. PCE concentrations in the air at 6 feet above the ground often exceeded the levels reported for soil pore gas at 5.5 feet below the ground surface.

TCE was found at only 9 sites. Soil pore gas TCE concentrations among those sites varied over 6 orders of magnitude (values ranged from 0.0002 to 100 micrograms per liter of gas).

SOIL SAMPLING

Phase two of the field investigation involved collection and analysis of soil samples during the week of March 24 from areas of reported high solvent concentrations in soil pore gas. URS provided overall supervision of the soil sampling effort. Field sampling operations involving both URS and ERM-West were directed by ERM-West, with J.H. Kleinfelder and Associates and James M. Montgomery Laboratories retained by URS as drilling and analytical laboratory subcontractors, respectively.

Selection of Sites

Soil sampling sites were located at or near the seven sites where high concentrations of TCE and PCE were reported in soil pore gas. Potential sources of TCE and PCE contamination indicated by the Task 1 efforts were also considered in locating sampling sites. Special attention was also given to the

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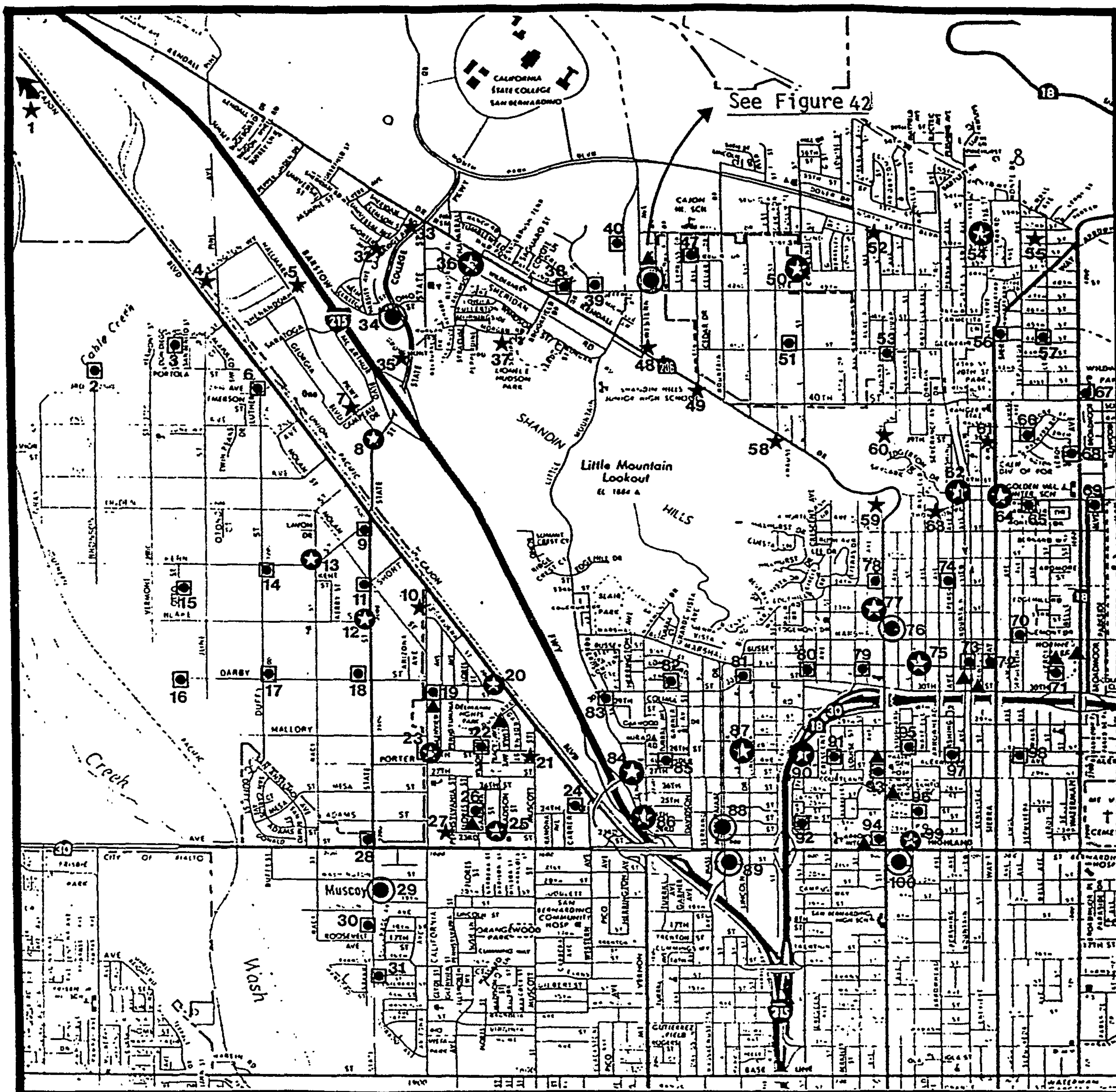

Figure 40. SOIL PORE GAS CONCENTRATION - PCE

LEGEND

★ PCE present; near background; ≤ 0.001 ug/l
▣ Low PCE; 0.001 < PCE ≤ 0.01 ug/l
✪ Moderate PCE; 0.01 < PCE ≤ 0.1 ug/l
◉ High PCE; PCE = 0.1 to 10.0 ug/l
▲ Closed Well

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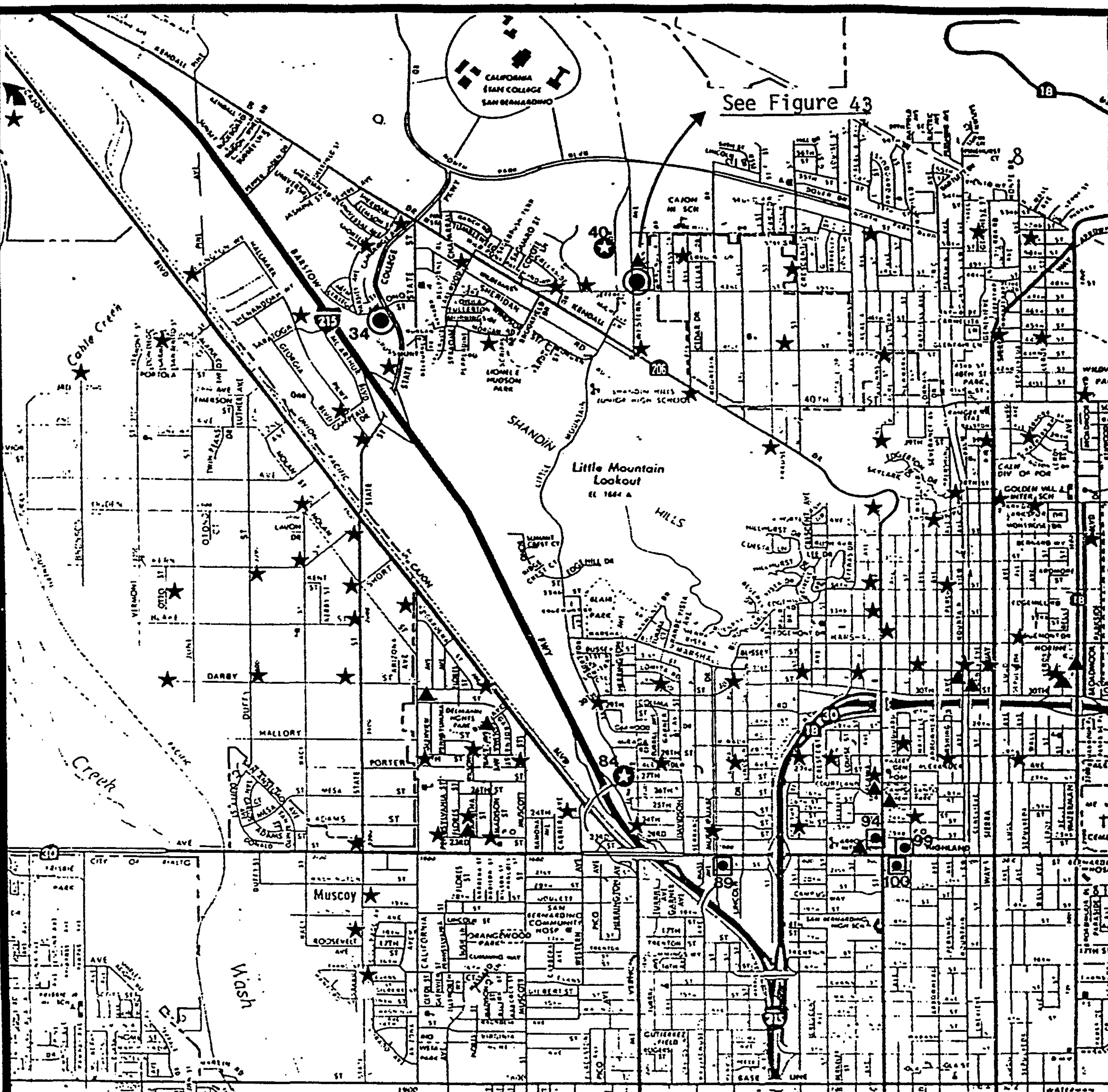

Figure 41. SOIL PORE GAS CONCENTRATION - TCE

LEGEND

★ Sampling Site; TCE ≤ 0.0002 (detection limit)

Low TCE; 0.0002 < TCE ≤ 0.001 ug/l

Moderate TCE; 0.001 < TCE ≤ 0.10 ug/l

High TCE; 0.10 < TCE ≤ 100 ug/l

▲ Closed Well

N

0 .25 .5
MILES

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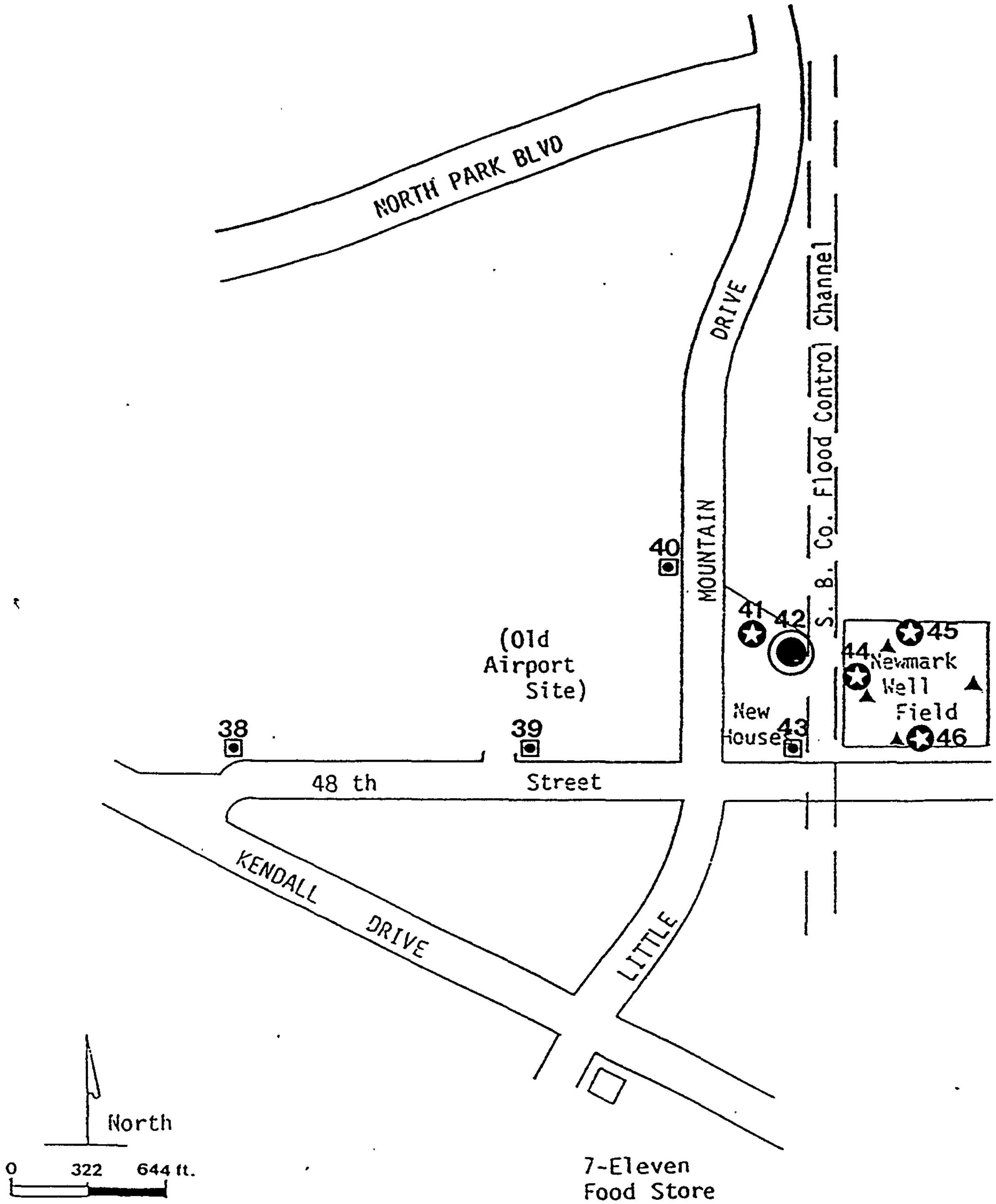

LEGEND

- Low PCE; $0.001 < PCE \leq 0.01$ ug/l
- Moderate PCE; $0.01 < PCE \leq 0.1$ ug/l
- High PCE; PCE = 0.1 to 10.0 ug/l
- ▲ Closed Well

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Figure 42. SOIL PORE GAS CONCENTRATION - PCE NEWMARK WELLFIELD

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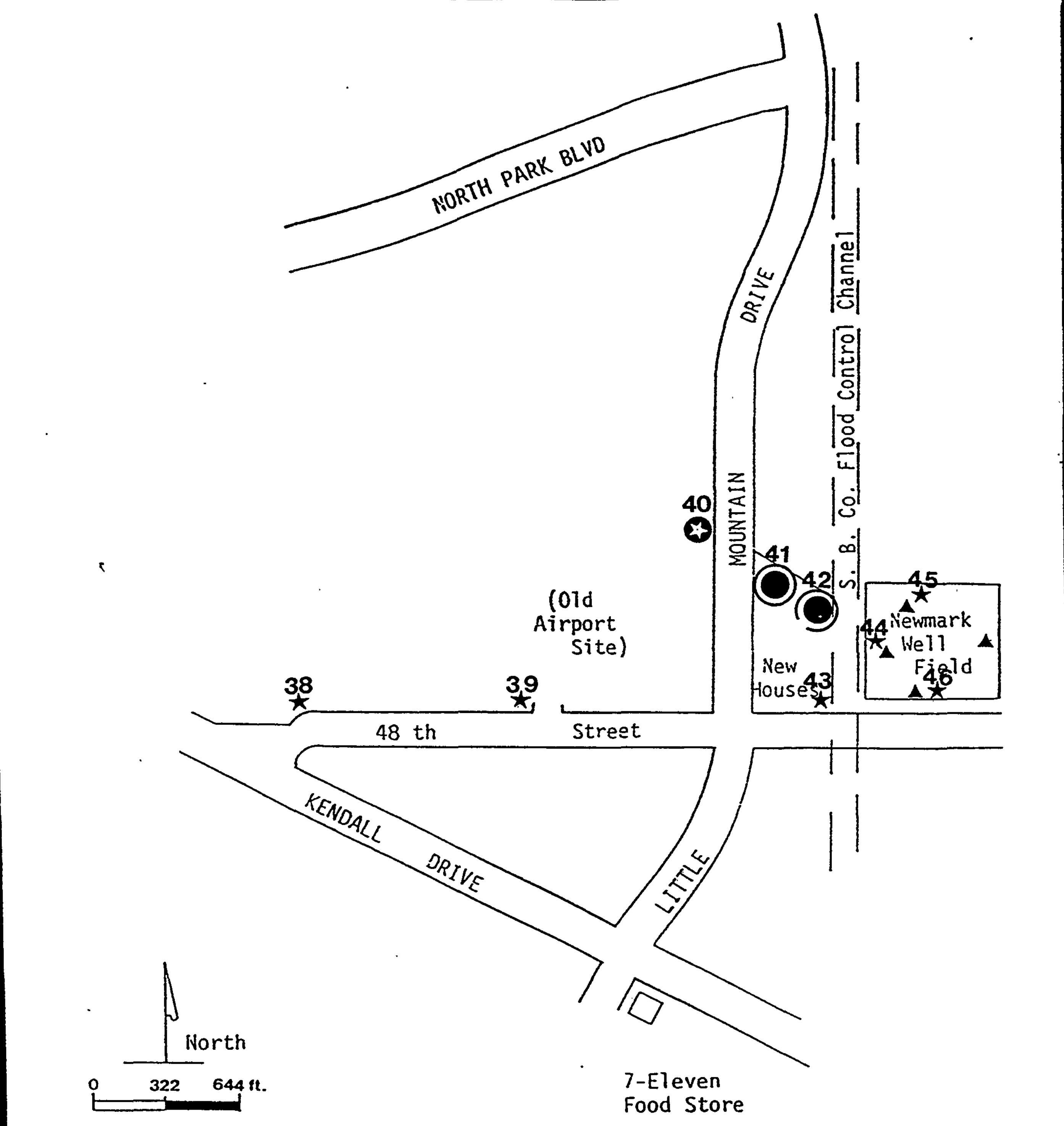

LEGEND

★ Sampling site; TCE ≤ 0.0002 ug/l (detection limit)

Moderate TCE; 0.001 < TCE ≤ 0.10 ug/l

High TCE; 0.10 < TCE ≤ 100 ug/l

▲ Closed Well

Figure 43. SOIL PORE GAS CONCENTRATION - TCE NEWMARK WELLFIELD

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CITY00233

Table 7.

SOIL PORE GAS FIELD RESULTS FOR TCE AND PCE
February 24-28, 1986

Map #	Original Site #	Location	Tracer Sample Number	Value ug/l-gas TCE	Value ug/l-gas PCE
1	--	Cajon Dump, West of Palm and Cajon	77	ND*	.001
2	GG	Northern Deadend of Bronson St.	99	ND	.002
3	HH	Northern Deadend of Carmelina St.	76	ND	.002
4	C	West End of Lexington Way	74	ND	.0008
5	2	Hallmark and Saratoga Way	73	ND	.001
6	II	3rd Ave. and Duffy St.	75	ND	.002
7	1	Hallmark and Campeau Dr.	72	ND	.001
8	3	Hallmark and University	71	ND	.02
9	76	Kern and State St.	70	ND	.004
10	75	Cajon and California St.	66	ND	.001
11	79	Nolan and State St.	68	ND	.01
12	80	Blake and State St.	101	ND	.02
13	77	Kern and Macy St.	69	ND	.02
14	R	Duffy and Kern St.	100	ND	.002
15	78	3141 Otto St.	78	ND	.002
16	73	West End of Darby St.	103	ND	.008
17	Q	Darby and Duffy St.	102	ND	.009
18	71	2020 Darby St.	67	ND	.002
19	70	30th and Darby (Darby Well)	62	ND	.002
20	74	Cajon and Darby St.	65	.0001	.06

* ND = Not Detectable

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CITY00234

Map #	Original Site #	Location	Tracer Sample Number	Value ug/l-gas TCE	Value ug/l-gas PCE
21	65	On Muscott Between 28th and Porter	58	ND	.001
22	66	28th and Wilson St.	60	ND	.002
23	67	28th and California St.	61	ND	.05
24	81	On 24th West of Western Ave.	79	ND	.004
25	62	23rd and Madison St.	57	ND	.04
26	--	Gardena Well	59	ND	.002
27	61	West End of 23rd St.	56	ND	.001
28	60	State and Highland Ave.	98	ND	.002
29	59	On State between 19th and Washington St.	95	ND	.2
30	58	South of 1804 State St.	97	ND	.004
31	56	State Street Well	96	ND	.006
32	6	Shorter and Varsity Ave.	14	ND	.0008
33	7	East End of Sheridan Rd.	13	ND	.0008
34	4	SW Corner of College Ave. & University Pkwy.	64	2.0	40.0
35	5	Eastern Deadend of Varsity Ave. near University	63	ND	.0005
36	D	Lakewood & Kendall Drive	11	ND	.06
37	10	Morgan Road and Lionel Hudson Park	10	ND	.001
38	E	48th and Creekside Road	9	ND	.008
39	F	48th St. East of Sun Valley Drive	8	ND	.004
40	11	On Little Mtn. Dr. ¼ mile north of 48th Street	7	.004	.001

Table 7, Continued, Page 3 of 6

Map #	Original Site #	Location	Tracer Sample Number	Value ug/l-gas TCE	Value ug/l-gas PCE
41	--	Across Road from "CAT Pit" on Private Road	33	.6	.08
42	--	50 Feet East of "CAT Pit"	5	100.0	4.0
43	13	48th and Flood Control Channel	6	ND	.01
44	15	100 yds West of Newmark Well #3	4	ND	.02
45	16	Between Newmark Wells #1 and #4 (3 feet)	2	ND	.04
45	16	Between Newmark Wells #1 and #4 (5.5 feet)	3	ND	.02
45	16	Between Newmark Wells #1 and #4 (9 feet)	3	ND	.1
46	14	Newmark Well #3	1	ND	.02
47	AA	4th Avenue and Reservoir Drive	34	ND	.02
48	17	Western and Kendall Drive	32	ND	.0006
49	18	4th Avenue and Kendall Drive	31	ND	.0008
50	BB	4264 N. E Street	35	ND	.02
51	20	On 41st St. Between E and F St. (county)	36	ND	.003
52	CC	E St. and Sequoia St.	29	ND	.001
53	21	44th and E St.	28	ND	.002
54	DD	5215 Genevieve St.	37	ND	.02
55	EE	51st and Leroy St.	38	ND	.0001
56	23	44th St. and Sierra Way	39	ND	.005
57	24	44th St. and Leroy St.	40	ND	.008
58	19	Kendall Dr. and F St. (County)	30	ND	.0008

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Table 7, Continued, Page 4 of 6

Map #	Original Site #	Location	Tracer Sample Number	Value ug/l-gas TCE	Value ug/l-gas PCE
59	G	Acacia Way North of 36th St.	26	ND	.0008
60	22	South End of Acre Lane	27	ND	.0009
61	25	39th St. and Sierra Way	42	ND	.001
62	--	38th St. and Mtn. View Avenue	50	ND	.02
63	31	Thompson Place and Arrowhead Ave.	51	ND	.001
64	30	Sierra Way and Parkdale Dr. (37th St.)	52	ND	.02
65	29	Sepulveda Ave. and Parkdale Dr.	53	ND	.004
66	26	Sonora Dr. and Ralston Ave.	41	ND	.002
67	--	40th St. and Waterman Ave. (Wildwood Park)	43	ND	.0007
68	27	Waterman Ave. and Ralston Ave.	55	ND	.002
69	28	Broadmoor and Parkdale Dr.	54	ND	.002
70	37	Sepulveda Ave. and Marshall Blvd.	16	ND	.004
71	38	On Leroy St. Between 30th and Marshall (Leroy Well)	15	ND	.005
72	39	Sierra Way and 31st St.	17	ND	.004
73	40	Mtn. View Ave. and 31st St.	20	ND	.005
74	33	34th St. and Pershing Ave.	49	ND	.008
75	41	D St. and 31st St.	18	ND	.06
75	41	D St. and 31st St.	44	ND	.01
76	--	3255 E St. (South of 33rd St)	45	ND	.2
77	--	On 33rd St. Between E and F St.	46	ND	.04
78	H	Acacia Ave. and 34th St.	25	ND	.004

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Table 7, Continued, Page 5 of 6

Map #	Original Site #	Location	Tracer Sample Number	Value ug/l-gas TCE	PCE
79	I	Acacia Ave. and 31st St.	19	ND	.004
80	42	H St. and 31st St.	21	ND	.004
81	43	30th St. and Ladera Road	22	ND	.002
82	N	1256 Lynwood Drive	83	ND	.008
83	44	Little Mtn. Dr. and 30th St.	81	ND	.01
84	45	Little Mtn. Dr. and 27th St.	80	.002	.07
85	"O"	1266 Alexander Ave.	82	ND	.008
86	P	Miramonte Dr. and 24th St.	94	ND	.02
87	46	2777 Ladera Rd. (South of Mirada Rd.)	84	ND	.02
88	55	On Muscupiabe Dr. (South of 24th St.)	85	ND	.4
89	--	Muscupiabe Dr. and 21st St.	88	.0003	.2
90	47	28th and H St.	87	ND	.06
91	48	28th and G St.	84	ND	.003
92	J	24th and H St.	86	ND	.004
93	49	27th and Acacia St.	24	ND	.001
94	54	E St. and 23rd St. (At Well)	23	.0002	.01
95	50	D St. and 28th St.	90	ND	.003
96	K	D St. and 24th St.	93	ND	.008
97	51	28th St. and Pershing Ave.	91	ND	.004
98	52	28th St. and Sepulveda Ave.	92	ND	.006

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Table 7, Continued, Page 6 of 6

Map #	Original Site #	Location	Tracer Sample Number	Value ug/l-gas TCE	Value ug/l-gas PCE
99	--	Highland and D St.	47	.001	.04
100	--	In Alley Behind 480 W. Highland Ave. (Cleaners)	48	.0007	8.0

* ND = Not Detectable

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CAT Pit site, in response to the reported nature of this operation and its proximity to the Newmark wells. Figures 44 and 45 show soil sampling locations.

To avoid difficulties with site access, most soil sampling sites were located on public rights-of-way with approval by the City of San Bernardino. Because past disposal of solvents to land has more likely occurred on private property than on public property, the sampling sites (with the exception of those at the CAT Pit) probably do not coincide exactly with the actual waste disposal sites. As discussed below, this situation probably influenced very significantly the final results obtained.

Methods

Samples were collected using a California drive-tube sampler fitted with three six-inch brass tubes. Boring and sampling were performed with a hollow-stem auger with the sampler advanced into undisturbed soil below the augers by repeated blows from a 140 pound hammer with a 30-inch drop. All augers were steam cleaned before work commenced and between successive uses. Sampling equipment was routinely cleaned in the field using Alconox detergent solution, followed by successive rinses with deionized water.

Boring logs were prepared for each hole, summarizing lithology based on observations of auger cuttings and soils recovered inside the samplers. The boring logs also included observations made during sampling, indicating depths at which soil samples were collected and providing the number of hammer blow counts required to advance the sampler.

Cuttings from each hole were shoveled into 55 gallon drums (which were D.O.T approved for hazardous waste storage and disposal) and transported to a City-owned and fenced area to await disposal. Following sample collection, each bore hole was sealed with a 30:70 mix of bentonite clay and sand. Those bore holes located in asphalt areas were additionally capped with asphalt.

Samples taken were immediately capped, labelled, packaged, logged, chilled onsite and hand carried to the laboraty on the morning following each sampling day. Chain- of-custody forms listing specific information about every sample accompanied each set of samples to the lab.

Results

Only one of the 84 soil samples analyzed for TCE and PCE showed a barely detectable level (i.e., 0.1 mg/kg) of TCE. This sample was taken from a 34 foot depth at the site (#1, Figure 45) having the highest soil pore gas values for TCE and PCE (i.e., 100 micrograms per liter and 4.0 micrograms per liter, respectively). This site was also adjacent to the CAT Pit. This sample had a noticeable chemical odor at the time of collection.

DISCUSSION

PCE was detected in all soil pore gas samples, with a minimum reported concentration of 0.001 microgram per liter, which is only twice the minimum detection limit of 0.0005 micrograms per liter. Throughout the study area there

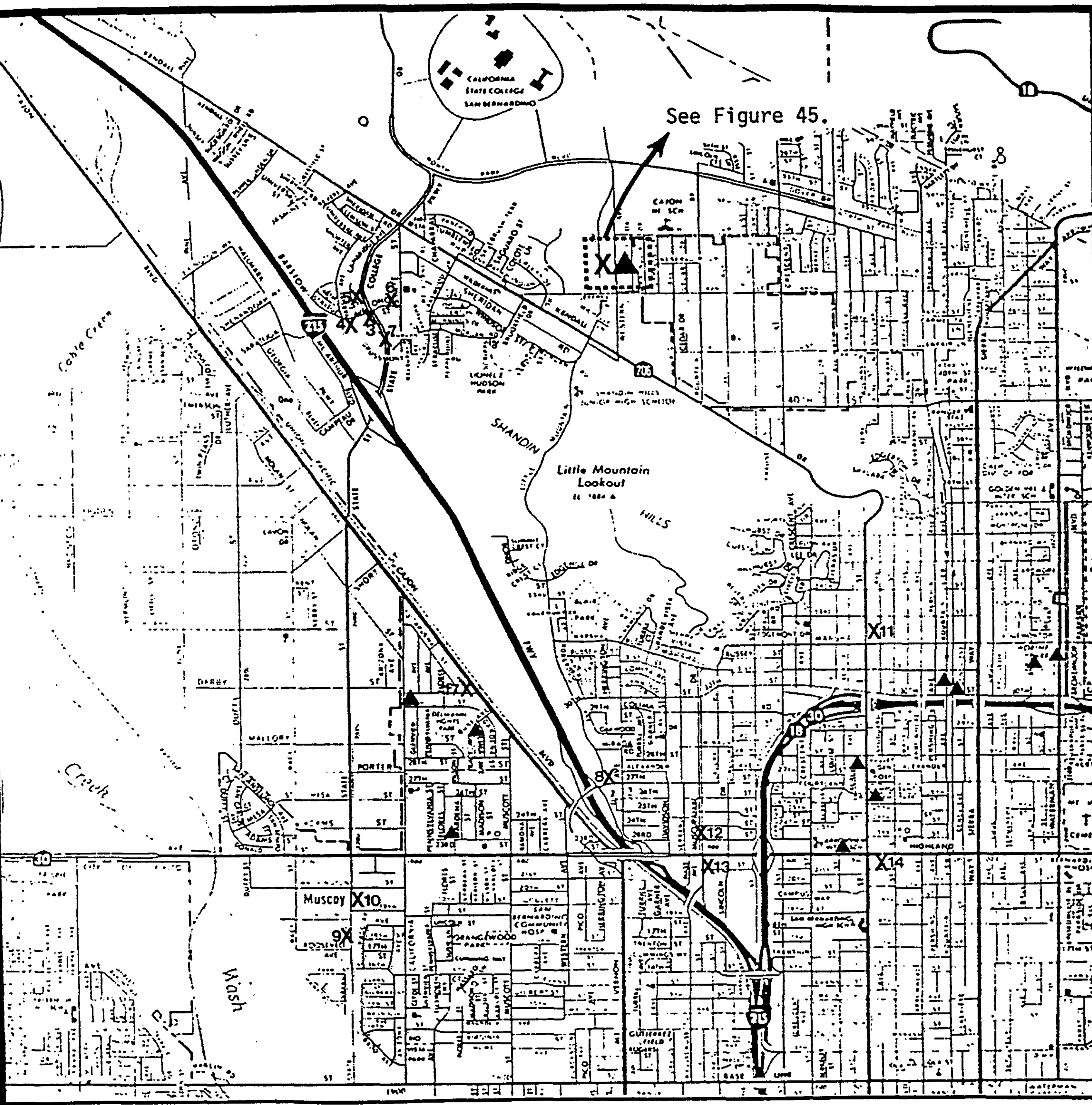

Figure 44. SOIL SAMPLE LOCATIONS

N

LEGEND

X Soil Boring Site

▲ Closed Wells

0 .25 .5 MILES

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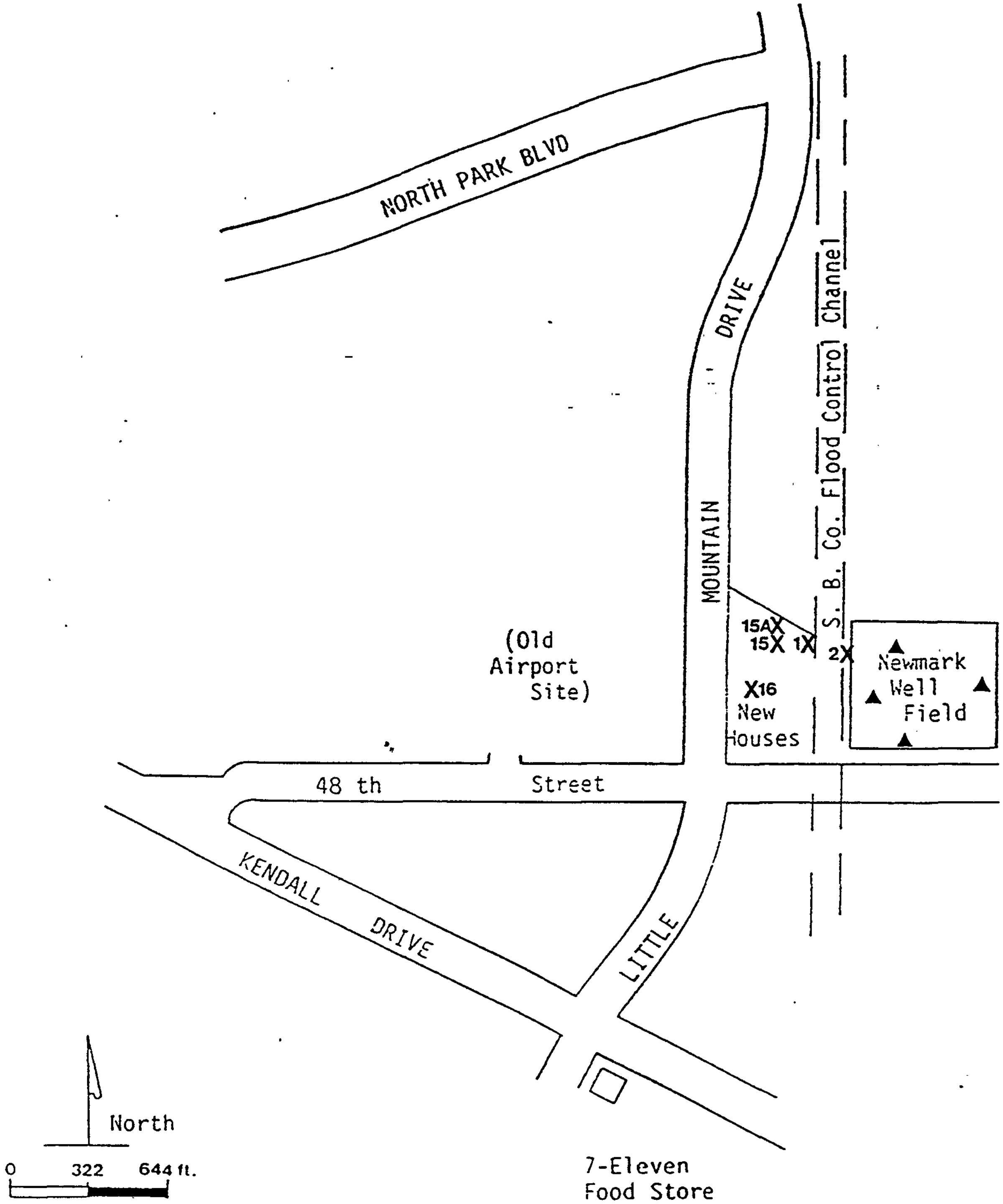

Figure 45. SOIL SAMPLE LOCATIONS AT THE NEWMARK WELLFIELD AREA

LEGEND

X Soil Boring Site

▲ Closed Wells

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were broad sections in which soil pore gas concentrations were consistently and uniformly in the range of 0.001 to 0.01 microgram per liter. These broad areas at background levels were punctuated by distinct areas with significantly greater solvent concentrations. After consideration of these factors it was concluded that for purposes of review and analysis of soil pore gas PCE concentration data, only those values exceeding 0.01 microgram per liter exceed background (defined as 0.001 ug/l in the earlier figures) sufficiently to warrant particular attention.

The occurrence of PCE in ambient air during the study does not appear to have influenced study results. In the portion of the study area lying south of 34th Street and west of Muscupiabe Drive, pore gas investigations were conducted on February 25, 26 and 28. During this period, PCE concentrations reported by TRC in ambient air increased from 0.0006 micrograms per liter on the 25th to 0.03 micrograms per liter on the 28th. Despite this increase, reported PCE concentrations in soil pore gas samples do not appear to be generally higher in samples collected in this area later in that week.

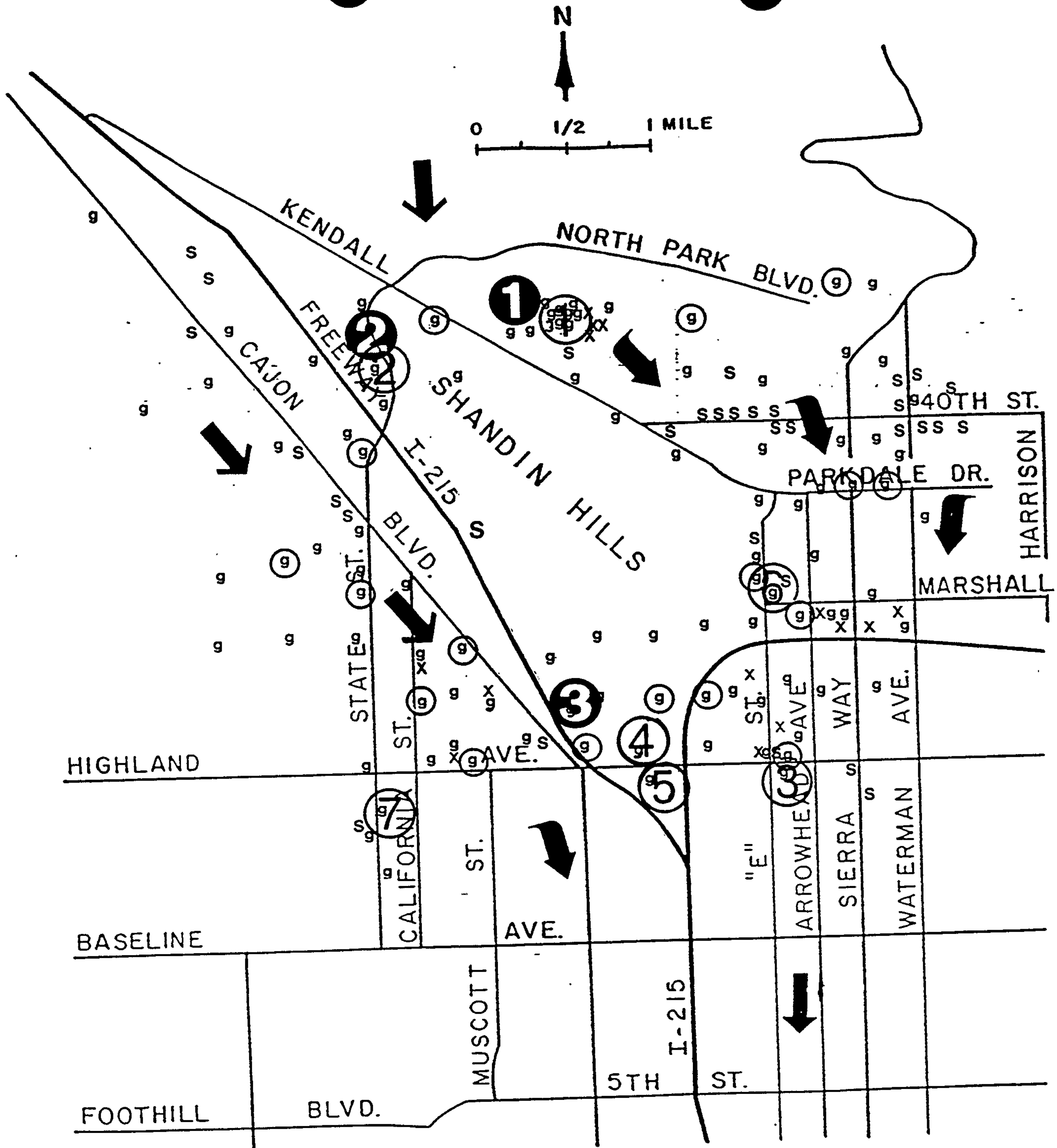
Earlier discussions stated that soil sampling was conducted in the areas where the greatest amounts of TCE and PCE were detected in soil pore gas. Nevertheless, with only one exception (at 34 feet), no solvents were detected in soil samples. Thus, TCE and PCE detected in soil pore gas (at 5.5 feet) may have been associated with the occurrence of traces of these chemicals on area soils, but the soil pore gas results probably reflect TCE and PCE levels in the groundwater below.

As indicated previously, the soil pore gas sampling grid was arranged primarily to investigate the occurrence of significant groundwater contamination and to provide some general indications as to the areas within which potential sources could be found. The results do not indicate the existence of one or two large plumes extending through much of the area. Rather, as indicated in a summary figure -- Figure 46, the observed pattern is much more one of numerous localized areas of increased concentrations, including such previously suggested major potential contamination sources as Camp Ono and the old San Bernardino and Shandin Hills Airports.

Elevated levels of TCE were reported in three areas, near Camp Ono and the San Bernardino and Shandin Hills Airports. As these sites showed elevated concentrations of PCE in soil pore gas, these sites appear to be potentially significant sources of TCE and PCE concentrations.

Another feature of interest was the pattern of moderate to high PCE levels in soil pore gas along Highland Avenue extending the entire width of the study area. This band is distinct and separate from other areas of reported high concentrations of PCE in soil pore gas and cannot be attributed to any one or a few large sources. Rather, the pattern more nearly suggests a line of numerous dischargers, smaller in contaminant output than the Camp Ono or airport sites.

As reported previously, detectable solvent concentrations were found in only one soil sample. This sample was collected at a 34 foot depth adjacent to, and just down-gradient from, the CAT Pit. This sample also had a noticeable chemical odor. In contrast, samples from just upgradient did not indicate



Major Potential Sources (Significant TCE in Gas)

g Gas Sampling Site

High PCE in Gas

Groundwater Flow Direction

S Minor Potential Sources

Moderate PCE in Gas

x = Closed Wells

Figure 46. GAS RESULTS COMPARED WITH SOURCE LOCATIONS AND GROUNDWATER FLOW

contamination, even though to the best of available information, the upgradient site was close to being directly over the CAT Pit.

Close examination of drilling records and consideration of probable past practices provide a highly plausible explanation for these results. The CAT Pit reportedly was exactly that -- a pit. When it was abandoned, some contaminated material was reportedly removed, but the pit itself was obviously refilled. Because it would almost certainly have been filled with clean material, samples collected at this site would likely not show contamination unless the sample were collected from a depth below the base of the fill. At both the upgradient site and its twin (about 5 feet away), auger refusal occurred at 25 to 30 feet. This is above the depth at which chemical odors and TCE were found at the downgradient site. Furthermore, since the CAT Pit would conceivably have been filled with any clean fill conveniently at hand, it would not be surprising if the fill material were large gravel, boulders, and/or demolition debris. Thus it is probable that the upgradient borings did not penetrate the CAT Pit fill.

The almost universal absence of significant amounts of fine-grained soil in the upper subsoil profiles in the study area is consistent with the hydrogeologic data presented in Chapter 4. This is an important feature, since it indicates the absence of any significant barriers to vertical transport of contaminants through the upper portions of the vadose zone. These conditions also favor successful use of soil pore gas investigation techniques, should such sampling methods be considered for future studies.

Chapter 6.

CONCLUSIONS

This study included review and identification of former and continuing businesses that might have been significant users of TCE and PCE plus review and evaluation of available hydrogeologic data, and analyses of soil pore gas soil samples for TCE and PCE. Based on the results and findings of all these efforts, the following major conclusions are indicated:

- The observed contamination patterns do not appear to be attributable to a small number of major contamination sources.
- Much of the observed contamination appears to result from the combined contributions of numerous smaller contributors.
- Additional investigations of certain contamination sites appear warranted.

Each of these conclusions is discussed in more detail below.

MANY SOURCES

The observed contamination patterns do not appear to be attributable to one or a small number of major contamination sources. Since before this study began, there has been some conjecture concerning the existence of a major plume of TCE-and-PCE-contaminated water extending from the former Airport and Camp Ono areas to municipal water supply wells as far away as south of Highland Avenue in San Bernardino. The pattern of discovery of TCE and PCE in various City of San Bernardino wells in the study area also presented an apparent picture of a plume steadily advancing southward into the main basin.

This study team was aware of these concerns from the outset, and considerable effort was expended in this study to investigate that hypothesis and, if it were verified, to identify the responsible sources. The available hydrogeologic and water quality data and the soil pore gas analysis data discount the "Supersource" hypothesis. These factors are discussed below.

Water Quality Data

A first impression of the historical data on TCE and PCE concentrations in area wells could suggest a general plume, since virtually all domestic water supply wells between about the Newmark wellfield to the north and Highland Avenue to the south have shown some concentrations of TCE and PCE since 1980. The greatest concentrations have also been observed at the Newmark wellfield, generally upgradient of the other contaminated wells. In addition, TCE and PCE were first identified in 1985 in a number of City of San Bernardino wells south of the Crosstown Freeway (30th Street), creating an appearance of a southerly advancing plume.

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These data must be interpreted cautiously however. The municipal water supply wells affected are actually not situated conveniently nor drilled to appropriately uniform or even broad depths for them to serve well as a monitoring network for the hydrogeologic behavior throughout the region. There are indeed wide variabilities in the casing-perforation or slotting depths, and water samples have been produced from a variety of depths within the aquifer. Relative contributions of water and contaminants from the various producing intervals at a single well are not clear. Differences in well construction and screening also make it difficult to compare adjacent wells. (The discussion of the Southern California Water Company's Delmann Heights wells in Chapter 3 makes this clear.) Furthermore, historically fluctuating operating schedules pretty much ensure that samples collected from a given well at different times do not represent equivalent groundwater conditions, and it is highly unlikely that samples from neighboring wells -- drilled to different depths and operated differently -- represent the same or similar hydrologic conditions.

The findings of TCE and PCE in wells south of 30th Street do not necessarily indicate rapid plume advancement. The 1985 results were the first analyses of water from these wells for TCE and PCE. These wells had not been sampled previously, because they were inactive.

In view of these limitations on the use of production wells for groundwater contamination plume identification and mapping, their TCE and PCE water quality data should be considered semi-quantitative. Constraints and limitations on the data should be recognized and considered in interpreting and using the data. As discussed further below, an areally spread set of sources of TCE and PCE can also explain the observed patterns in municipal water wells and is more consistent with findings of other investigations performed in this study.

Hydrogeology

As discussed in detail in Chapter 4, the estimated time of travel for TCE and PCE to move from the Camp Ono and former Airport areas to Highland Avenue is too long by a factor of at least 4 to account for contamination as far south as Highland Avenue. These estimates are based on substantial and reliable work by other researchers regarding groundwater basin hydrogeology and characteristic movements of TCE and PCE in aquifers.

Soil Pore Gas Analysis

The soil pore gas sampling network was constructed to maximize the probability of identifying major areal groundwater contamination plumes, as might be associated with the "Supersource" scenario. The grid was regarded as generally capable of identifying "plume" features having about a one-mile extent and concentrations between 5 and 150 ug/l.

As discussed in Chapter 5, it is believed that the PCE concentrations detected in soil pore gas analyses generally reflected PCE presence in groundwater. Accordingly, if the Supersource hypothesis were valid, the soil pore gas analysis should have shown elevated PCE concentrations at or near contamination source areas to the north and west, with a consistent dimunition in concentrations toward the southernmost wells. Furthermore, given the effects

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of contaminant dispersion and dilution in groundwater and the gradation to finer aquifer materials (implying greater retardation) in a southerly direction, the concentrations in the pore gas should generally have decreased from north to south along the axis of the plume, even decreasing more rapidly moving to the south or southeast.

As the soil pore gas data from Chapter 5 indicate, the observed soil pore gas patterns do not match the Supersource construct. Although some high results were obtained at sites near the former Camp Ono and Airport sites, there is no indication of large areal plumes extending downgradient from these sources. In addition, across the southerly end of the study area, PCE concentrations in soil pore gas were consistently higher than those at immediately upgradient sites. This indicates that the sources were nearby or that the trailing edge of a plume passing below Highland Avenue had been found. The PCE data over 5 years at the southerly wells (Figures 38 and 39) had indicated that plumes had already passed by the Gardena and Colima Street wells, but concentrations at the Darby well and the Waterman - Mt. View area wells remained virtually unchanged with time. The only remaining conclusion is that sources of contamination are near sampling sites with high readings that are downgradient of sites with low readings.

These factors taken together reinforce the conclusion that the observed contamination patterns cannot be attributed to one or a small number of large sources. The alternative conclusion, that multiple contributions occurred from numerous small(er) sources in addition to suspected large(r) sources, is again supported.

SMALL SOURCES

Much of the observed contamination appears to result from the combined contributions of numerous smaller contributors. An alternative hypothesis to contamination being attributable to one or a small number of sources is the combined contributions of numerous sources of varying size. This is consistent with observed inventories of potential contamination sources, permeability of area soils, estimated distances of contaminant movement from sources, and soil pore gas data. The inventories of potential sources and permeability of area soils indicate the potential for multiple small sources to create contamination problems. Discussions of estimated distances of contaminant movement from sources and the soil pore gas data establish that the multiple small source scenario is the most plausible explanation for the observed contamination patterns.

Inventories of Potential Contamination Sources

In Chapter 3, we presented data to identify and catalog potential sources of TCE and PCE within the study area. It is apparent that there have been a wide variety of enterprises and activities that are potential solvent users throughout the study area. Few of the facilities could be classified in any sense as major industrial activities, and many of them, such as automotive repair shops and dry cleaners, are very small businesses.

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This inventory of potential sources is undoubtedly incomplete since it was prepared from field observations and reviews of the business sections of old telephone books. During the fieldwork, several instances of storage of 55-gallon drums at private homes in the study area were observed. No effort was made to identify the origins or uses of these drums; however, in some cases it appeared that the property owners were involved in mechanical repairs, and their drums were likely associated with those activities.

These observations are undoubtedly not unique to the San Bernardino area. Halogenated solvents have been distributed and used widely in the economy, and the plethora of potential users (and disposers) identified in this particular area merely reflects that fact.

Permeability of Area Soils

Even though there are many potential sources of TCE and PCE in the study area, local vadose zone characteristics greatly influence the susceptibility of groundwater to contamination. This is particularly important for small discharges for which subsoils of low permeability and high absorptive capacity may provide some protection of groundwater from contamination. Thus it is appropriate to examine available information on area subsoils.

Chapter 4 presented evidence of the area's lithology, including three cross-sections based on reported well logs. No evidence of any significant clay or silt layers in the vadose zone were indicated; all reports indicated extensive deposits of highly permeable sands and gravels.

Results of the soil boring activities discussed in Chapter 5 are consistent with these logs and reports. Most of these borings were completed to 40 feet. Only minor amounts of silts and clays were identified in these borings, and cobbles and gravel were frequently noted in the logs.

These observations were also consistent with current general areal geologic processes. In recent and current geologic times, virtually the entire study area has been undergoing active alluvial deposition. The close proximity of the study area to the sources of alluvium has resulted in these observed deposits of coarse, highly permeable materials.

This lithology is highly significant. Throughout the study area there is little barrier to the downward migration of liquid. Some liquids and their contaminants will be removed by adsorption and entrapment in capillaries and pores, but these processes are much less effective than the barrier effects and retardation that would be created by indurated deposits of dense clay layers. Because such clay layers do not exist over most of the study area, local soils are not effective barriers to solvent movement to groundwater, and even small sources could be contributing to the observed contamination pattern.

Estimated Distances of Movement of Contaminants

In connection with the review of available hydrogeologic data, the maximum likely distance of movement of contaminants was extrapolated, based on likely time frames for contaminant release, estimated groundwater flow rates, and

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aquifer characteristics. This indicated that sources for the observed solvents in wells would likely be located within about one mile. Contaminated wells in the southern part of the study area alone span an area almost four miles long, east-to-west. Based on this consideration the possibility that all of these wells could have been contaminated by only one or two sources is not likely. Furthermore, as the orientation of this string of wells is east-to-west, or nearly perpendicular to the general groundwater flow direction, the possibility of only two sources affecting all these wells is accordingly even more remote.

Soil Pore Gas Data

As discussed previously, the soil pore gas data suggest a number of localized, distinct hot spots, as well as a broad area of elevated soil pore gas levels along Highland Avenue between State Street on the west to at least Arrowhead Avenue on the east. Figure 46 overlayed potential PCE and TCE sources inventoried in Chapter 3 on top of results of the soil pore gas testing. That figure indicates some correlations between identified hot spots and inventoried potential TCE and PCE sources. For example, high pore gas concentrations in the Camp Ono area, near the Newmark wellfield, near the old Shandin Hills Airport, and along "E" Street near Highland Avenue and Marshall Avenue correlate fairly well with noted potential sources. In other areas, however, the correlation is not as strong. In particular, no specific potential sources were noted near high soil pore gas concentration findings in the Muscoy and Delmann Heights areas. In addition, despite the numerous potential sources inventoried along 40th Street, soil pore gas concentrations were relatively low in that area.

Considering the probable incompleteness of the inventory of potential sources, the occurrence of high concentrations of PCE in soil pore gas in areas where there are no inventoried potential sources is not surprising. More detailed investigations in those areas could reveal still more sites warranting more detailed investigation.

FUTURE STUDIES RECOMMENDED

Additional investigations of potential contamination sources appear to be warranted. At the outset of this study it was hoped that specific sources for the identified contamination problems could be identified. While numerous potential sources have been inventoried and some likely contributing sources have been identified, direct implicating evidence is available only for the CAT Pit; and, as discussed below, even the CAT Pit data are not entirely conclusive.

The inability to implicate a number of potential sources conclusively follows directly from the breakdown of the "Supersource" hypothesis. Had this hypothesis been validated, the results of the hydrogeologic review and soil pore gas analyses would have distinctly shown few highly suspicious sites, following which intensive soil sampling should have shown more direct evidence of contamination. Instead, upon completion of the soil pore gas analyses, there were a variety of potential sites, including seven locations where especially high PCE concentrations in soil pore gas were detected.

The constraints of this study did not allow for detailed investigations of the multiple, localized sources indicated by the study. Accordingly additional follow-up work should be performed to provide direct evidence linking specific sites to groundwater contamination problems. Results of this study demonstrate the role of multiple sources in contributing to observed contamination patterns. Specific areas with notably high concentrations include Camp Ono, the former San Bernardino and Shandin Hills Airports, the Muscoy-Delmann Heights area, and much of the southern boundary of the study area, including the area along "E" Street as far north as Marshall Boulevard. With the exception of the former San Bernardino Airport the following actions are suggested:

- Investigation of waste disposal practices at individual enterprises and, if warranted, environmental sampling at specific inventoried potential PCE/TCE sources.

- Additional soil pore gas analyses. These analyses should be performed on a finer grid than that used in this study to discriminate individual suspect sites and to seek evidence of individual plumes.

Installation of a network of groundwater monitoring wells could be undertaken in lieu of soil pore gas monitoring. However, areal geologic conditions are almost ideal for the use of the soil pore gas analysis technique, and it is believed that the soil pore gas testing used in this study responded to groundwater PCE levels. In view of the relative costs, the soil pore gas investigation method is recommended for identification of sites requiring detailed investigation. Installation of groundwater monitoring wells may be appropriate in conjunction with more detailed investigations after a suspect site is identified.

Specific site investigations appear to be warranted in the area of the former San Bernardino Municipal Airport. The results of this study strongly indicate at least one potential source of contamination at the CAT Pit site. The description of activities of this site provided by our anonymous source indicates a major source of potential contamination at this site. The information provided by him is further corroborated by aerial photographs, soil pore gas analytical data, and analyses of soil samples. Considering the closeness of this site to the Newmark wells, there is substantial, direct data indicating a significant potential for groundwater contamination associated with activities at this site. Even with these corroborative findings, however, there are still some major uncertainties associated with this site that indicate a need for further investigation.

First, the extent and overall significance of the site is still unclear. Since soil samples were not obtained all the way from the disposal area to groundwater nor of groundwater immediately upgradient and downgradient of the site, there are not data conclusively and directly linking this site to groundwater contamination. Rather, the concerns about this site are inferential, but strongly based.

Second, there are some anomalies between analytical data from the CAT Pit site (from soil pore gas and soil sampling results) and contamination patterns observed at the Newmark wells. The soil pore gas analyses indicated significantly greater levels of TCE than PCE. Also, TCE was detected in soils at

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34 feet, but not PCE. In contrast, at the Newmark wellfield PCE levels have been significantly greater than TCE levels. Similarly the nature of business activities at the airport suggests that the resulting contamination should comprise a mixture of various organics, including significant amounts of alkanes, alkenes, and other petroleum hydrocarbons associated with fuels and oils. However, analyses of water from the Newmark wells using EPA Methods 624 and 625 (Gas chromatographic/mass spectrometric analyses for volatiles and acid- and base/neutral extractable organics) indicated only the presence of TCE and PCE.

These factors suggest that there may be other contributing sources of PCE in the vicinity of the Newmark wells in addition to the CAT Pit. In this regard, it should be remembered that the site was actively used as an airport for many years, and the CAT Pit activity only commenced following the closure of the airport. Ancillary airport activities generally include aircraft maintenance and repair, which have historically involved the use of solvents such as TCE and PCE. Accordingly, while the potential importance of the CAT Pit should be recognized, simultaneously it must be remembered that there may be other significant sources of TCE and PCE in the area.

Another site that may warrant further investigation is the former Shandin Hills Airport that existed prior to World War II northwest of the intersection of 27th Street and Mt. Vernon Avenue. Little is known about the airport. Its existence was discovered only in the review of the yellow pages from old telephone books and was confirmed through analysis of a 1938 aerial survey of the Valley. Elevated PCE levels were found in soil pore gas in and around this area, and one of the three significant TCE findings (out of 100 sites) was virtually on top of this old airport site.

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Appendix A

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Appendix A.

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Aug. 15, 1986

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Not for Publication

APPARENT HISTORICAL GROUNDWATER VELOCITIES IN THE BUNKER HILL BASIN

by

Michael B. Sonnen

A 1985-86 study by URS Corporation of municipal well contamination with TCE and PCE in northwestern San Bernardino concluded the the rates of water and contaminant movement through the aquifer materials involved were probably much too slow for all the contamination now found over a 15 square-mile area to have originated at a single source. Members of the local water resources community were unconvinced and appear to continue to subscribe to a theory of very rapid groundwater movement in the area of interest which is used to support a single, or perhaps double, "Supersource" hypothesis. The following is a compilation of all the URS computations, based on data amassed by others, which shows repeatedly that groundwater flow velocities are too small or travel times are too long for the Supersource theory to remain very plausible.

Interstitial water velocity can be calculated from Darcy's Law as follows:

$$V = (K \times S)/P$$

where,
- V = groundwater flow velocity
- K = aquifer hydraulic conductivity = T/b
- T = aquifer transmissivity
- b = thickness of aquifer
- S = groundwater surface gradient
- P = porosity of the aquifer materials.

To use this equation to calculate groundwater flow velocities, the aquifer was divided into elements and the groundwater surface gradient and hydraulic conductivity were determined for each element. The estimated flow velocity for each element was then calculated from these data.

The aquifer elements were extracted from the U.S. Geological Survey finite-element model for the Bunker Hill Basin (USGS, September 1980). Figure 36 shows the area covered by the elements used in this study.

Transmissivities for each element were taken from the same report. The average depth of alluvium was estimated from the data from Fife et al. (1976), as reported by Rasmussen (October 1985). As the model is built on a two-layered aquifer system, transmissivity values for the upper and lower layers were generally averaged to estimate the transmissivity for each element. Because the transmissivities of the upper and lower layers were generally within 25 percent of each other for most elements, this is a reasonable approximation. In two cases (elements 75 and 89) there were substantial differences between transmissivities for the upper and lower aquifers. In

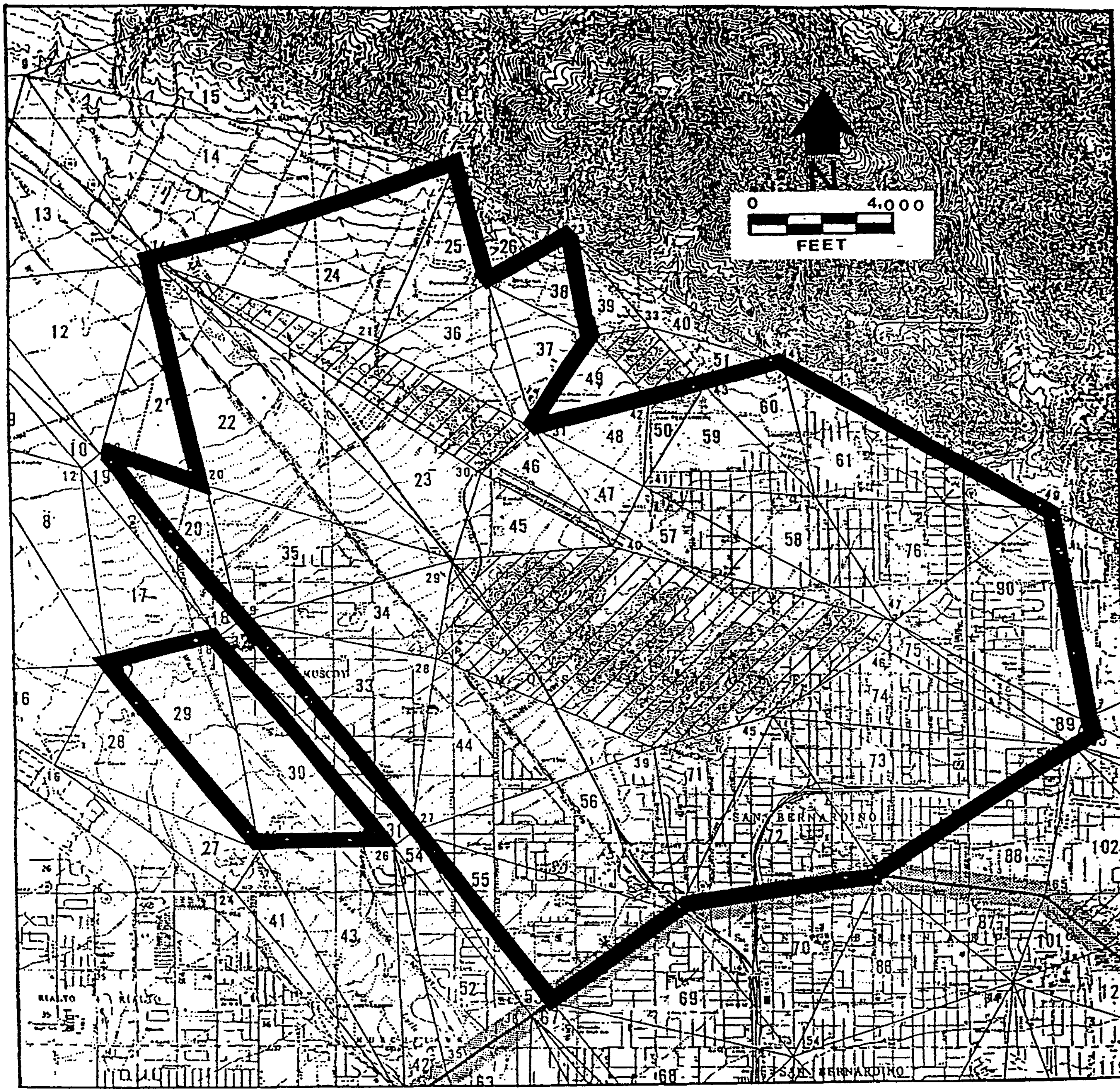

Figure 36. USGS MODEL ELEMENTS FOR WHICH GROUNDWATER FLOW VELOCITIES WERE ESTIMATED

(Source: Hardt and Hutchinson, 1980)

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these cases, the transmissivity value for the upper aquifer was used. (It is interesting to note that these two elements are long and narrow, and they were obviously drawn this way by USGS (Hardt and Hutchinson, September 1980) to represent Fault K. They were assigned identical transmissivity by the modelers, and it is doubly interesting to note that they were assigned the 4th-largest values of transmissivity of the 29 elements used here.)

Groundwater flow velocities in the aquifer pore spaces were calculated by multiplying the groundwater surface gradients (scaled from Figures 29 to 31) times the transmissivities from the USGS model, and dividing by the depths of saturated alluvium from Fife et al. and by the porosity of each model element. The values of porosity (ranging from 0.3 to 0.4) were taken from Todd (1980), who lists porosities for general aquifer materials of the Bunker Hill type ranging from 28 percent for coarse gravel to 42 percent for clay.

The selected data and the computed transport rates for groundwater are shown in Table 4 for 1965, 1975, and 1985. Also shown are contaminant (PCE) transport rates, which are simply the velocities divided by 3.0, our chosen retardation factor.

The range of historical groundwater velocities shown in the table is from 0.09 to 5.92 feet per day, or .00625 to 0.41 mile per year. Travel times, then, are the inverse of velocity which range from 160 down to 2.4 years per mile of travel. The range of PCE transport rates was, obviously one-third that of the water: 0.03 to 1.97 feet per day; the unit travel time being 480 down to 7.3 years per mile.

The interstitial water can be seen, therefore, to have moved through the basin at typically very low rates. Groundwater does not move very fast; Todd (1980) reports that while the rates vary widely, "values from 2 meters/year to 2 meters/day are normal." The 0.09 foot/day found here is equivalent to 10.0 meters/year, and the largest velocity found here of 5.92 feet per day is equivalent to 1.8 meters/day. So the computed Bunker Hill basin velocities are within what Todd (1980) has termed the "normal" range.

Despite finding flow velocities for the Bunker Hill basin to be in the normal range from 1965 to 1985, as determined from data measured by others, a number of reviewers of an earlier draft took strong issue with the URS computations, suggesting that the figures were considerably at odds with those derived by others with groundwater experience in the area. In all fairness, these reviewers and others had discovered an error in the earlier work -- namely, a failure to divide computed velocities by the porosity. Performing the correct computations, however, which are those now shown in Table 4 (of the Final Report and included herein), merely brought the range of historical values more into the "normal" range and did not change the conclusion that, like everywhere else, regional groundwater flow is a sluggishly slow process in the Bunker Hill basin.

Because other work had recently been reported on the same subject, however (i.e., TCE and PCE movement in the exact same subregion of the Bunker Hill basin), and because that work was published first and left a much different impression of speed of movement through the basin, it is worth dwelling on other indications than Table 4 of how slow groundwater flow through the study area must be.

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Table 4.

COMPUTED GROUNDWATER AND CONTAMINANT TRANSPORT RATES

Elmt. No.	Est. Por., p	Avg. T, ft²/d	Alvm Depth, ft	Hyd. Cond., ft/d	Water Table Surface Gradient 1965		1975		1985		Groundwater (GW) and Contaminant (CON) Transport Rates, ft/day 1965 Spring		1965 Fall		1975 Spring		1975 Fall		1985 Spring		1985 Fall	
					Spring	Fall	Spring	Fall	Spring	Fall	GW	CON	GW	CON	GW	CON	GW	CON	GW	CON	GW	CON
20	0.35	6178	400	15.44	0.017	0.021	0.019	0.020	0.016	0.015	0.75	0.25	0.93	0.31	0.84	0.28	0.88	0.29	0.71	0.24	0.66	0.22
22	0.37	6178	500	12.35	0.016	0.022	0.022	0.024	0.016	0.015	0.53	0.18	0.73	0.24	0.73	0.24	0.80	0.27	0.53	0.18	0.50	0.17
23	0.30	2061	300	6.87	0.022	0.023	0.024	0.025	0.020	0.017	0.50	0.17	0.53	0.18	0.55	0.18	0.57	0.19	0.46	0.15	0.39	0.13
29	0.33	8873	700	12.67	0.017	0.021	0.019	0.020	0.016	0.015	0.65	0.22	0.81	0.27	0.73	0.24	0.77	0.26	0.61	0.20	0.58	0.19
30	0.33	6783	700	9.69	0.017	0.021	0.019	0.020	0.016	0.015	0.50	0.17	0.62	0.21	0.56	0.19	0.59	0.20	0.47	0.16	0.44	0.15
33	0.38	6178	400	15.44	0.017	0.021	0.019	0.020	0.016	0.015	0.69	0.23	0.85	0.28	0.77	0.26	0.81	0.27	0.65	0.22	0.61	0.20
34	0.38	6178	200	30.89	0.017	0.021	0.019	0.020	0.016	0.015	1.38	0.46	1.71	0.57	1.54	0.52	1.62	0.54	1.30	0.44	1.22	0.40
35	0.36	6178	200	30.89	0.017	0.021	0.019	0.020	0.016	0.015	1.46	0.49	1.80	0.60	1.63	0.54	1.72	0.57	1.37	0.46	1.29	0.43
44	0.37	5707	400	14.26	0.017	0.021	0.019	0.020	0.016	0.025	0.66	0.22	0.81	0.27	0.73	0.24	0.77	0.26	0.62	0.21	0.96	0.32
45	0.38	2061	100	20.61	0.014	0.022	0.019	0.025	0.015	0.012	0.76	0.25	1.19	0.40	1.03	0.34	1.36	0.45	0.81	0.27	0.65	0.22
46	0.38	4225	200	21.12	0.014	0.022	0.019	0.025	0.015	0.012	0.78	0.26	1.22	0.41	1.06	0.35	1.39	0.46	0.83	0.28	0.67	0.22
47	0.38	4968	200	24.84	0.014	0.009	0.019	0.025	0.018	0.012	0.92	0.31	0.59	0.20	1.24	0.41	1.63	0.54	1.18	0.39	0.78	0.26
48	0.38	2320	200	11.60	0.014	0.022	0.048	0.017	0.018	0.028	0.42	0.14	0.67	0.22	1.47	0.49	0.52	0.17	0.55	0.18	0.85	0.28
50	0.38	2320	200	11.60	0.034	0.040	0.048	0.029	0.018	0.028	1.04	0.35	1.22	0.41	1.47	0.49	0.89	0.30	0.55	0.18	0.85	0.28
55	0.40	8238	800	10.29	0.017	0.021	0.019	0.020	0.016	0.013	0.44	0.15	0.54	0.18	0.49	0.16	0.51	0.17	0.41	0.14	0.33	0.11
56	0.39	8238	700	11.26	0.017	0.021	0.019	0.020	0.016	0.029	0.51	0.17	0.63	0.21	0.57	0.19	0.60	0.20	0.48	0.16	0.88	0.29
57	0.38	4968	100	49.68	0.013	0.011	0.015	0.017	0.018	0.015	1.70	0.57	1.44	0.48	1.96	0.65	2.22	0.74	2.35	0.78	1.96	0.65
58	0.38	2320	200	11.60	0.013	0.053	0.048	0.056	0.018	0.015	0.40	0.13	1.62	0.54	1.47	0.49	1.71	0.57	0.55	0.18	0.46	0.15
59	0.38	2320	200	11.60	0.013	0.048	0.048	0.029	0.018	0.028	0.40	0.13	1.47	0.49	1.47	0.49	0.89	0.30	0.55	0.18	0.85	0.28
60	0.38	467	200	2.34	0.048	0.048	0.060	0.040	0.018	0.028	0.29	0.10	0.29	0.10	0.37	0.12	0.25	0.08	0.11	0.04	0.17	0.06
61	0.30	700	200	3.50	0.064	0.053	0.074	0.056	0.018	0.028	0.75	0.25	0.62	0.21	0.86	0.29	0.65	0.22	0.21	0.07	0.33	0.11
71	0.39	6187	400	15.46	0.005	0.006	0.004	0.006	0.009	0.020	0.20	0.07	0.24	0.08	0.16	0.05	0.24	0.08	0.36	0.12	0.79	0.26
72	0.38	6501	750	8.67	0.017	0.006	0.004	0.006	0.009	0.020	0.39	0.13	1.37	0.46	0.09	0.03	1.37	0.46	0.31	0.07	0.46	0.15
73	0.36	10429	500	20.85	0.022	0.017	0.006	0.017	0.016	0.014	1.27	0.42	0.98	0.33	0.35	0.12	0.98	0.33	0.93	0.31	0.81	0.27
74	0.35	13034	300	43.44	0.022	0.017	0.007	0.017	0.016	0.033	2.73	0.91	2.11	0.70	0.87	0.29	2.11	0.70	1.99	0.66	4.10	1.37
75	0.40	8096	300	26.98	0.012	0.017	0.020	0.040	0.019	0.014	0.81	0.27	1.15	0.38	1.35	0.45	2.70	0.90	1.28	0.43	0.94	0.31
76	0.35	2204	200	11.02	0.074	0.074	0.080	0.040	0.053	0.120	2.33	0.78	2.33	0.78	2.52	0.84	1.26	0.42	1.67	0.56	3.78	1.26
89	0.40	8096	300	26.98	0.012	0.017	0.020	0.040	0.019	0.014	0.81	0.27	1.15	0.38	1.35	0.45	2.70	0.90	1.28	0.43	0.94	0.31
90	0.35	5184	300	17.28	0.083	0.074	0.080	0.071	0.019	0.120	4.10	1.37	3.65	1.22	3.95	1.32	3.51	1.17	0.94	0.31	5.92	1.97

The hydrogeologic report prepared by Rasmussen (April 1985) for the San Bernardino Municipal Water Department was a precursor to the October 1985 report by Rasmussen to the same client on TCE and PCE flow paths through the same region covered by the URS study. The April 1985 report (Rasmussen) contained very useful background information on the geology and aquifer characteristics of the area. It concluded, as URS did, that Fault K is not an important or significant barrier to groundwater movement between the Shandin Hills and Perris Hill; it influenced the URS interpretation of the Shandin Hills as a major separation of groundwater flow in the study area into two distinct southeastern paths; and it introduced URS to literature that it also found and reviewed. The report lamented that "The rate at which the contaminated water is moving is not known;" and it said further, despite the work by Water Resources Engineers (1969) and the USGS modeling work reported by Hardt and Hutchinson (1980) and by Mallory (1979), "None of the studies conducted on the basin to date indicates the time it takes ground-water to move from one part of the basin to another." The report also placed great emphasis on the potential of recharge at the upper end of the basin, specifically the Devil Canyon and Waterman Canyon - Twin Creek spreading basins, to influence the rate at which water is moved through the basin.

Then in three consecutive sentences, the first two of which I believe to be absolutely correct, the Rasmussen report (April 1985) appears to have led the Municipal Water Department and probably other interested parties astray:

> Because the lower portion of the basin is under a confined condition (artesian), any <u>surge</u> of recharge above normal that enters the basin upgradient of the confining beds will follow the laws of hydraulics and have a nearly instantaneous increase in the pressure at the low end of the basin. The <u>ground-water does not actually move through the basins at this rate</u>: only the pressure is transmitted.
>
> <u>Based on observation of the change in ground-water levels</u> at various locations in the Valley, we postulate that <u>it takes 1 to 1½ years</u> for the upper or shallowest ground-water <u>to move from the point of recharge to the lower end</u>. (Rasmussen, April 1985, p.8; emphasis added.)

The conclusion in the third sentence is truly unfortunate, given the preceding two sentences -- which are true or very nearly true. The conclusion in the third sentence is false, as I believe I can demonstrate below.

First, the changes in <u>levels</u> of groundwater (obviously noted at discrete wells) are -- as the Rasmussen report noted -- indicative of pressure changes, not gross water movements. Many wells throughout the basin show annual cycles of seasonal rises as a result of recharge. The annual drops and rebounds are on the order of 50 feet; that is 50 feet down and 50 feet back up. The wells where this occurs as a result of recharge and withdrawals at remote locations are showing a 100 foot movement in the open well per year merely as a result of transmitted pressure increases or decreases. The water level in the well has changed 100 feet per year, and the velocity could be estimated as 100 ft/year, divided by the porosity, which would yield an interstitial velocity of roughly 300 ft/year.

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On the other hand, it is 7.2 miles from the Waterman Avenue spreading grounds to the lower end of the basin or about 38,000 feet. That the water (not the pressure) moves 38,000 feet in 1 year is an assertion apparently in error by a factor of at least 100.

Consider some other data. In 1973 the importation of State Project Water to the Bunker Hill basin was roughly 34,000 acre-feet, and 23,000 acre-feet were recharged through the 137-acre Waterman spreading basins. The ponded water entered the ground, therefore, at an apparent velocity of

$$\frac{23{,}000 \text{ A-ft/yr}}{137 \text{ A}} = 168 \text{ ft/yr}$$

In the interstices or pore spaces the velocity was greater than that by a factor of one-over-the-porosity

$$\frac{168 \text{ ft/yr}}{0.37} = 454 \text{ ft/yr}$$

This was the apparent seepage velocity of a vertical column of water in a particularly porous part of the basin chosen specifically for its favorable water-accepting properties. If the remainder of the basin were equally porous and transmissive of water laterally toward the lower end, 38,000 feet away, it would have taken the water (not the pressure)

$$\frac{38{,}000 \text{ ft}}{454 \text{ ft/yr}} = 84 \text{ years}$$

to get from "the point of recharge to the lower end."

In his textbook on groundwater hydrology, Todd (1980) gives reported values of recharge rates in managed recharge basins throughout the United States, most of which were in California. The range of recharge rates (presumably the rate of all of the ponded water, not the interstitial flow velocity) was 0.1 to 2.9 meters per day (0.33 to 9.5 ft/day). One of Todd's (1980) reported locations was the Santa Ana River basin, where the recharge rates were reported to vary between 0.5 and 2.9 meters per day. Note that this basin displayed the highest rate in Todd's sample of 15 locations. Converting these rates to interstitial velocities in other units yields 1,620 to 9,400 ft/yr or 4.1 to 23.5 years per 38,000 feet. Quite naturally, no water travels through the entire basin at these rates; these are the rates at which water percolates or "falls" 100 feet or less down to the water table. (Contrast 9.5 ft/day with the velocity of any body including any quantity of water falling 100 feet through air, which takes 2.5 seconds and averages 40 ft/sec., the terminal velocity being 80.2 ft/sec. The average velocity of water falling through a vertical open pipe, then, would be 3,456,000 feet per day compared to 25.7 ft/day at Todd's (1980) highest reported seepage rate, divided by a porosity of 0.37. Even vertical seepage through a saturated portion of the generally unsaturated zone above the water table is slowed tremendously by the porous medium.)

Returning now to Table 4, the median values of the factors that affect ground-water velocity in the model elements used were

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$$T = 6{,}000\ ft^2/day\ (transmissivity)$$
$$b = 300\ ft\ (aquifer\ thickness)$$
$$dH/dL = 0.018\ ft/ft\ (water\ table\ gradient)$$
$$P = 0.37\ (porosity)$$

From Darcy's law, it is apparent that travel time can be computed from

$$t = \frac{PL}{(T/b)\ (dH/dL)}$$

If the median values of the Table 4 parameters characterized the entire San Bernardino Valley portion of the Bunker Hill basin, therefore, the travel time in the saturated zone from the "point of recharge to the lower end" would be

$$t = \frac{(0.37)\ (38{,}000)}{(6{,}000/300)\ (0.018)} = 39{,}056\ days = 107\ years,$$

not 1 year. The travel time for pollutants would be increased by R times, where R is the retardation factor.

Lastly, I note from Figures 29 through 31 -- the groundwater contours in the study area (upstream of the artesian, pressure zone) -- and from 1975 contours for the entire Bunker Hill basin given by Hardt and Hutchinson (1980), that the water-level gradient has ranged from 1,300 feet elevation near the recharge zone down to 950 feet elevation at the lower end of the basin 38,000 feet away. These data indicate an approximate groundwater flow velocity in the pore spaces of

$$v = (T/b)\ (dH/dL)/(P) = (20\ ft/day)\ (350/38{,}000)/0.37$$
$$= .498\ ft/day = 182\ ft/year$$

The travel time, therefore, would be

$$t = \frac{38{,}000\ ft}{182\ ft/yr} = 208\ years,$$

not 1.

All this discussion and the controversial disagreement with the URS earlier-draft findings are related directly to whether or not it is plausible for a single source of a few large sources in the northwestern, upgradient part of the study area to have been the source for all the TCE and PCE pollution now to be found in wells throughout the 15 square mile study area. The average travel time for the water to flow roughly 5 miles from the apparently largest but most remote sources (Camp Ono and the San Bernardino Airport) through the study area would require

$$t = \frac{0.37\ (5\ mi \times 5{,}280\ ft/mi)}{(6{,}000\ ft^2/day)/(300\ ft)(0.018\ ft/ft)(365\ days/yr)} = 74\ years$$

That is a conclusion based on measured water level gradients and on average aquifer characteristics in the USGS model (Hardt and Hutchinson, 1980). Others have speculated on the basis of only water level changes in wells that the speed must be 38,000 ft/yr, and hence a 5-mile travel time must be a little over 8 months. I am convinced that the 8-month estimate results from observing pressure translation and not water movement, and the 8 months may be more nearly what Rasmussen (April 1985) has called an "instantaneous" period for even pressure to be translated 5 miles in the real world of saturated porous media. The confusing result of this controversy is that the "Supersource" theory makes sense under Rasmussen's speculation, and it seems to be implausible from all my computations with previously measured data.

To close the discussion, I point out that even the URS calculations are for average conditions; water in the pressure zone moves more slowly than in the unconfined aquifer area of this study (Rasmussen, April 1985); water near pumping wells travels faster than the average regional flow-field velocity, and very localized solution channels or other features of locally higher-than-average permeability will result in much higher flows. In that light, I have computed radiuses of influence for 30 municipal wells from pumpage data for the 1979 to 1983 period. The results, including the areas of influence, are given in Table 5. The sum of all the areas of influence of the wells, pumping at their maximum recorded annual rates, is 4.3 square miles or 29 percent of the area if the Newmark wells are combined. The areas of influence of all wells other than the Newmark wells sum to 1.95 square miles or 13 percent of the 15 square-mile area. I repeat that the maximum flows for each well were chosen from 5 years, of pumpage data, so these maximum flows did not all occur at the same time (i.e., the area influenced by higher-than-average velocities was less than Table 5 suggests). It is also to be noted that the radius of influence, computed from (Todd, 1980) as:

$$r = \frac{Q}{2(T/b)(H)(dH/dL)}$$

implies that water was moved toward the well from all directions (radially) at higher-than-average velocities, which modulates this effect on regional flow-field velocities substantially if not totally.

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Table 5.

MAXIMUM ZONES OF INFLUENCE OF MUNICIPAL WELLS
1979-1983

Well Number	Local Designation	Highest Annual Flow, in Period,[1] gpm	Estimated Radius of Influence, feet	Estimated Area of Influence, sq. mi.
1	Antil #6	2,918	2,600	0.760
2	Arrowhead Country Club	279	429	0.007
3	Baseline & California	376	335	0.013
4	Colima	192	171	0.003
5	Darby	90	80	0.001
6	Ellena Brothers	482	430	0.021
7	Gardena	150	134	0.002
8	Gilbert	0	0	0
9	Leroy	813	725	0.059
10	Lynwood	798	711	0.057
11	Lytle Creek #3	1,308	1,166	0.150
12	Mallory	66	59	0.000
13	Mt. Vernon	289	258	0.007
14	Newmark #1	807*		
15	Newmark #2	1,591*		
16	Newmark #3	1,045*		
17	Newmark #4	1,708*	Sum *'s = 4,590	2.37
18	Perris Hill #5	472	421	0.020
19	State Street	116	103	0.012
20	Waterman Avenue	1,995	1,778	0.356
21	7th Street	1,863	1,660	0.311
22	16th & Sierra Way	0	0	0
23	17th & Sierra Way	0	0	0
24	19th St. No. 1	550	490	0.027
25	19th St. No. 2	366	326	0.012
26	23rd & No. "E" St.	0	0	0
27	25th & No. "E" St.	269	240	0.006
28	27th & Acacia	0	0	0
29	30th & Mt. View	769	685	0.053
30	31st & Mt. View	929	828	0.077

[1] Source: Annual Report of the Western - San Bernardino Watermaster for 1984, August 1, 1985.

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